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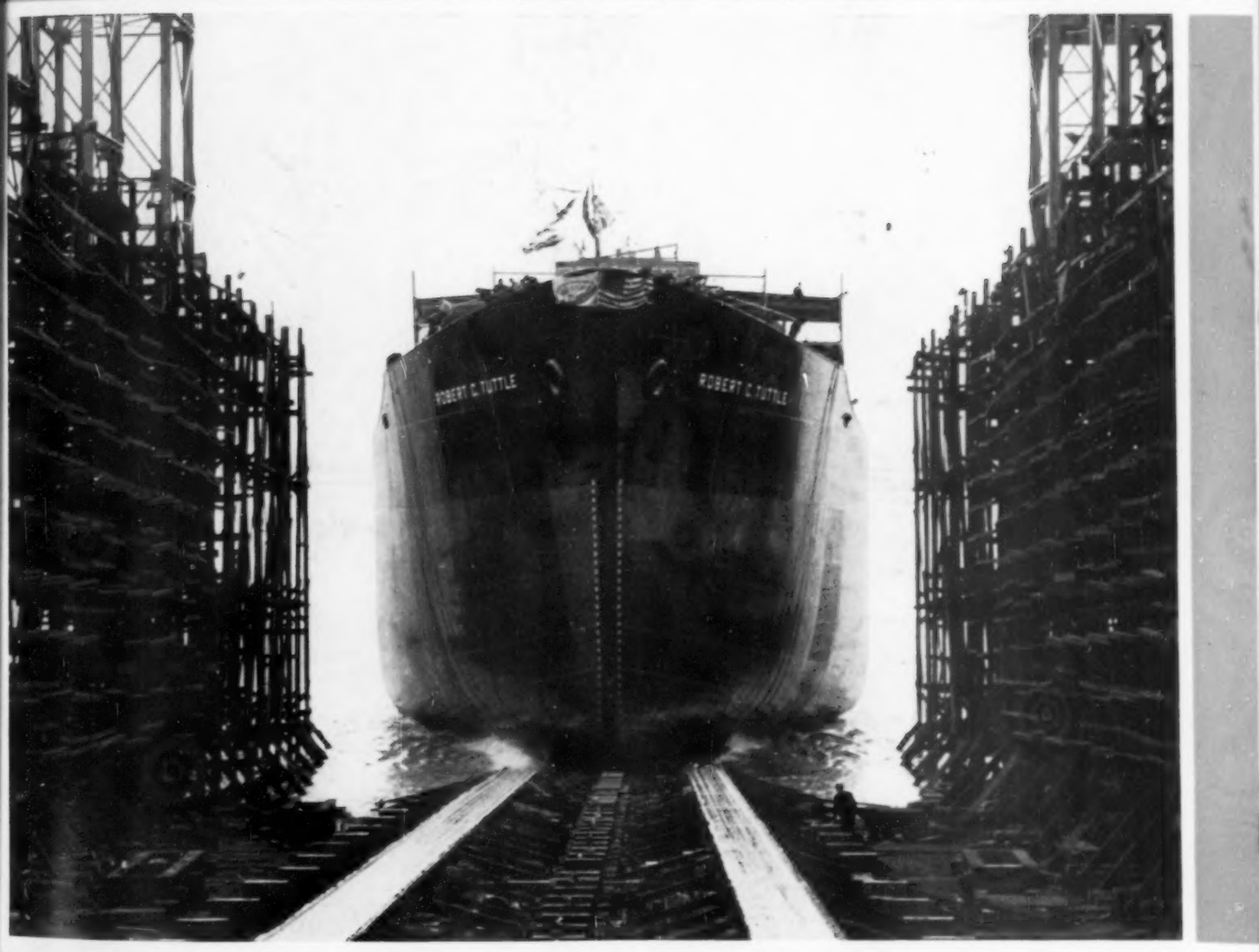

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Welding Journal

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METAL SPRAY PROTECTION OF Refinery Equipment*

By D. R. JOHNSON† and E. K. DEWEY, JR.†

UNTIL recently the term "metallizing" or metal-spraying would have been defined as a process whereby any metal which could be drawn into wire or reduced to powder form could be applied to any solid surface. This definition, to do complete justice to the advances continually being made in the equipment and the technique of handling it, must now be broadened. It might now be described as a process whereby any fusible substance susceptible of being reduced to powder form or drawn into wire can be deposited on any solid surface; thus recent advances have made it possible to spray Thiokol with a standard powder-type gun. Thiokol is a synthetic rubber having remarkable resistance to many deteriorative influences. The term "metallizing" has accordingly become slightly misleading; but lacking a more descriptive term for the process, we shall continue to use it.

Two types of spray guns are in general use today for metallizing, the wire-type in which the substance to be sprayed is fed to the gun in the form of wire and the powder-type in which the substance to be sprayed is first reduced to a finely pulverized form. Our experience has been solely with the wire type, but this can be considered accidental; and for completeness, the possibilities of the other type will be mentioned. The Schori powder spray gun has been relatively recently introduced into this country, although it has been widely used in Europe for many years. An interesting feature claimed for this process is that powdered metals may be blended in different proportions to produce alloy coatings having specific, desired properties. The powder process also holds forth the attractive possibility of being able to apply certain types of plastics and Thiokol, as previously mentioned.

Our attention has been directed recently to experimental work being done with an unusual type of gun. This gun employs an electric arc instead of gas to fuse the materials to be sprayed. Until recently certain inherent difficulties have stood in the way of practical development of the idea. If this development is successful, the cost of current should prove to be but a small fraction of the cost of acetylene or propane gas required in the case of either of the gas-type guns.

The wire-type gun has become the most widely used in this country. It is sufficiently common to justify a fairly complete description at this time. The gun itself weighs between $2^3/_4$ and 4 pounds, depending upon the type and size. The weight is kept as low as possible to minimize operator fatigue. The wire to be sprayed is pulled into the gun by knurled rolls turned by a turbine and gear mechanism. This turbine is rotated at high speed by compressed air. In the forward part of the gun, balanced amounts of oxygen, acetylene (or propane) and compressed air are admitted through a control valve having graduated slots. The gas and oxygen enter a mixing chamber and pass out through the gas nozzle. This gas nozzle encases the wire nozzle and is in turn encased in the air cap. With the gases ignited, the wire passes through the gun into the cone of the flame and is fused. A cone of cold compressed air surrounding the flame picks up the metal the instant it is melted and flings it forward into the field of deposit. The tiny globules of metal are estimated to travel at 30,000 feet per minute; but in the short distance of some four to five inches between the nozzle of the gun and the surface being sprayed, the temperature of the metal is apparently reduced to less than 200° F. The surface thus produced is consequently not of the same structure as cast metal or plated metal; neither does it fuse nor blend with the surface being coated but depends for its adhesion on minute irregularities of the surface being coated. Appropriate roughening of the surface to be sprayed will materially improve the bond. Under the best conditions this bond amounts to approximately 200 pounds per square inch.

The coating produced by metallizing is not homogeneous, since it results from the leafing of multitudes of tiny particles of semifluid metal. When such a coating is intended for corrosion protection, several layers are required to minimize the porosity. The necessary total thickness for impermeability or corrsion protection is from 0.012 to 0.020 inch, depending on the metal being sprayed. Generally speaking, eight to fifteen coats will be required to give this thickness, with fewer coats being required for the softer metals to obtain the same degree of impermeability or over-all thickness. Peening or wire-brushing are other devices recommended by some authorities for minimizing porosity.

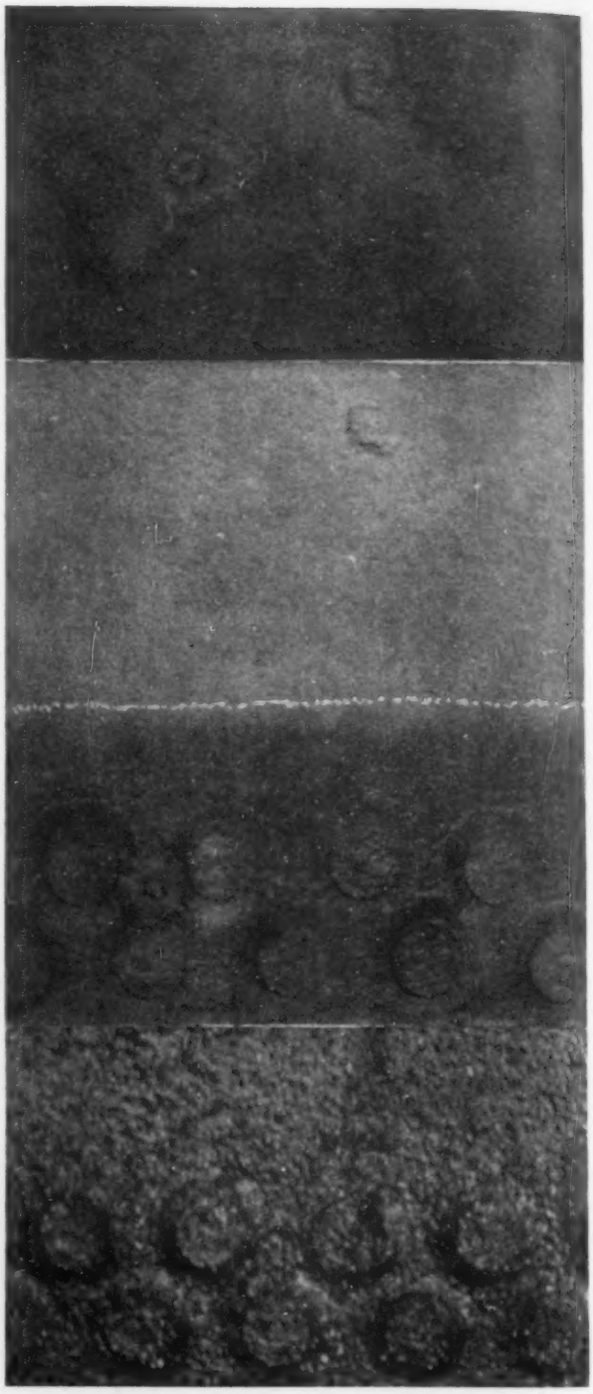
A proper engineering study is a necessary preliminary to a successful application of metal spraying. It should be ascertained whether corrosion, erosion or abrasion is involved before deciding on the material to be used. For example, it would be a waste of time and money to build up a pump rod with 18–8 when pure abrasion is involved. It would obviously be equally foolish to build up a rod at great expense with high-carbon steel if the hastiest investigation could disclose that a severe corro-

* Presented at Feb. 2nd Meeting, Oklahoma City Section, A. W. S.
† Continental Oil Company, Ponca City, Okla.

sive condition is involved. If pure abrasion or erosion is involved, high-carbon steel is usually adequate. Where pure corrosion is concerned, the corrosive should be studied, since a number of suitable metals or alloys may be at hand. For all-round resistance, 18–8 stainless steel would probably be the best; but under many circumstances, much cheaper materials, such as red brass aluminum or lead, will do as well. If a combination of corrosion and erosion is involved, 18–8 should perhaps be used. The thickness required must also be considered. If too thin, under certain conditions the coating will be permeable; and its purpose will be defeated. If too thick, under extreme temperature conditions differential expansion between the coating and the material being protected may result in a separation and resultant peeling or blistering. Coatings for corrosion protection too thick for one purpose may be too thin for another application under a different set of operating conditions.

We have found that the most important single factor in metallizing, either for corrosion protection or for building-up purposes, is the proper preparation of the surface to be coated. The surface should be prepared by sand-blasting to pure base metal. We suggest that ordinary river sand be avoided, using only first-quality blasting sand or steel grit. It has been found that the angle at which the sand-blast is directed has a material effect on the bond obtained. The optimum angle is considered to be approximately 60° to the surface. The air used for sand-blasting must be reasonably dry. The importance of keeping moisture away from a surface to be metallized cannot be overemphasized. Moisture on the surface causes the formation of a film of oxide which tends to diminish the bond materially. Even under the best of weather conditions, the area sand-blasted must not exceed that which can be sprayed during the same eight-hour shift in which sand-blasting is done. In moderately humid weather, metallizing should be done within four hours of sand-blasting. Sand-blasting or metallizing should not be attempted in wet weather. When preparing surfaces which have been in previous service and where coke or oil may be trapped in seams or under rivet heads, special care must be taken to remove such oil or coke. Heating with a torch is often necessary prior to sand-blasting.

In the metallizing operation itself, many of the same precautions should be taken as when sand-blasting. In this portion of the operation, the operator is the most important single factor. He must be fully qualified, both as to skill and personal reliability. The gun must be well cared for and in good condition. Very nearly absolutely dry air must be supplied to the gun. It is sometimes necessary to dry the air chemically. It is well to use only the highest grade metallizing wire furnished especially for this purpose. The size of wire used depends largely upon the gun itself. With a modified standard gun, good results have been obtained with eleven-gage wire. Gas pressure settings are important and are a function of the melting point of the metal being sprayed. Table 1 gives approximate settings for a few materials commonly sprayed.



Lower: Original Carbon-Covered Surface. Second: Carbon Removed by Blasting with River Sand. Third: Surface Fully Cleaned by Flint Sand Blasting, Ready for Metallizing. Upper: Final Surface Metallized with 18–8 Stainless. All Pictures Made with Same Exposure. Note That the Sand-Blasted Iron Appears Lighter Than the Metallized Surface. This Is Also True by Visual Examination

Table 1—Gas Pressure Settings

	Approximate Melting Point (° F.)	Acetylene Pressure (Pounds)	Oxygen Pressure (Pounds)	Air Pressure (Pounds)
Aluminum	1217	15	16	75
High-carbon steel	2560	19	20	80
Low-carbon steel	2680	19	20	80
Lead	620	13	14	75
Monel metal	2460	19	20	80
Red brass	1870	18	19	80
Stainless steel	2550	18	19	80

Before proceeding with metallizing, the operator should go over the work, making certain that the freshly prepared sand-blasted surface has not come in contact with anything moist or oily. There is a natural tendency to believe that the sand-blast is merely to roughen the surface and that the heat of the metallizing spray will remove the impurities. This is definitely not the case. If

there is any doubt as to the cleanliness of the surface, sand-blast again.

The possibilities of metallizing can best be illustrated by describing a few typical applications. Some of them have been very successful, and others have been only partially so. A few have been wholly unsuccessful. Cracking unit reaction chambers, dephlegmator towers, bubble towers, evaporators, lubricating oil contact kettles pump rods and plungers are examples of typical oil refinery equipment which have been successfully metallized.

An early major project was metallizing the top rings and domes of two 10-foot by 40-foot reaction chambers on a Dubbs cracking unit in January 1934. The temperature of the oil stream entering the chambers was 930° F. Originally the chambers had been designed to operate at 250-pounds gage pressure. Over a period of four years prior to metallizing, the maximum corrosion rate observed was 0.050 inch per year, while the average rate for all chambers was 0.036 inch per year. If corrosion had not been arrested by some type of coating, it would have been necessary to replace the vessels at an early date or to reduce pressures to such a point that operating efficiency would have been impaired.

When these two reaction chambers were inspected nine months after metallizing, it was found that the coating on the domes and the shells had been damaged. The aluminum coat on the domes had peeled badly over a large portion of the entire dome area. The peeling was attributed almost entirely to the fact that the original aluminum coat had been too thick. The damaged areas of the domes were sand-blasted and re-sprayed with only ten coats of aluminum having a total thickness of 0.018 inch. The damage to the metallizing on the shells of the chambers was somewhat different from the dome failures. In an attempt to facilitate inspection of the metallizing, the chamber was heated to dry and spall the adhering coke. Subsequent inspection showed that the metallizing had been damaged somewhat, indicating that either too high a temperature had been used or that localized over-heating had taken place during the spalling process. These areas were also sand-blasted and re-metallized with ten coats of aluminum.

Six months later, when the thinner coating on the domes and shells was inspected, the metallizing was found to be in good condition except for a small ring around each top manhole where most of the coating had been mechanically removed by the rotary cleaning equipment. In the case of the top rings of the shells, it was noted that, in spots where the coating seemed to have been destroyed by the rotary cleaning disks, the aluminum had actually been beaten into the steel. This supposition was supported by the fact that the steel could not be electrically welded without first chipping or sand-blasting. It is believed that protection from corrosion was obtained even after the aluminum appeared to be gone.

As a result of the final successful protection of these two original chambers, ten additional Dubbs reaction chambers were similarly metallized with aluminum. In the four and one-half years that have elapsed since the chambers were protected in this manner, there has been no measurable loss from corrosion.

Semi-annual inspection records on the twelve Dubbs reaction chambers show that an average of 4 to 5 per cent of the total area originally coated had to be re-metallized annually. This percentage would be materially lower were it not for the fact that rotary cleaning equipment is employed on these chambers. This average annual replacement varies from as little as one to as much as ten per cent for individual chambers. For example, the first chamber metallized has had 54 per cent of the original coating replaced in the last five years.

Satisfactory results have also been obtained by metallizing the bottom sections of dephlegmator towers on the same Dubbs cracking units with aluminum. Over a period of four and one-half years since metallizing, there has been no measurable loss from corrosion.

A typical example of a metallizing failure was experienced at an East Coast refinery when an attempt was made to apply metal spray to a reaction chamber. The chamber was part of a cracking unit processing high sulphur gas oil at 920° F. and 750 pounds gage pressure. The work was done by a local metallizing contractor. The job was a complete failure within a few months. Faulty application was obviously responsible, since numerous chambers operating under similar conditions had been metallized with complete success. The effect of high humidity prevailing at the time of metallizing could have been the cause. High humidity occurs during extended periods on the eastern seaboard, a factor which could very easily have been overlooked by an inexperienced contractor.

Experience has shown that, if metallizing work is to be contracted, the qualifications of the contractor are extremely important. The purchaser should have a qualified inspector check the work in the field whenever metallizing is handled in this manner. Some companies have found it advisable to do their own metallizing almost exclusively, but obviously this is not feasible in all cases.

Several metals other than aluminum can be successfully employed for protection against corrosion in refinery equipment. In a refinery at Artesia, New Mexico, the bubble tower of a cracking unit processing high sulphur topped crude had lost metal at the rate of 0.129 inch a year by localized corrosion and erosion. The tower was metallized in the corrosive zone with twelve coats of 18–8 stainless steel to a thickness of 0.020 inch. The fact that erosion was important in this case would have meant certain failure if aluminum had been used. Three inspections following the installation of the liner indicate that successful protection has been secured. Several similar applications at other refineries have proved entirely successful.

As a good example of a metallizing job which was not wholly successful, we mention the case of a contact kettle at a mid-continent refinery. The kettle in question is used for mixing acid-treated lubricating oils with contact clay prior to processing through a pipe still. Sulphur dioxide corrosion was therefore involved. A new vessel was sprayed with red brass before installation. The metallizing was done under unfavorable atmospheric conditions, namely, cold and damp weather. In this case, one of the fundamental rules governing good metallizing practice was violated.

Inspection of the vessel after a little less than two years' service showed that the coating had disappeared completely over about 5 per cent of the area, and much of the rest was blistered or actually starting to peel. Where a good metallizing bond had been secured, absolute protection had been afforded the parent metal. At the bare spots, the loss of steel varied from 0.020 to 0.115 inch. The original thickness of the plate was 0.500 inch.

A new steel contact kettle in similar service had lost as much by general thinning after $1^1/_2$ years as the metallized kettle had at localized spots in two years. The life of the unprotected kettle is estimated at 5 years as compared with an indefinite life for the metallized kettle provided the coating is repaired periodically.

Typical of the infinity of applications that can be successfully metallized are: the surfaces of storage tanks and drums, the ends of pipe still tubes, exchanger tube sheets, heads and shells and pump rods. For these pur-

poses, aluminum, red brass, 18–8 stainless steel, zinc and lead have been used.

Some of the best examples of the savings to be made by the use of the metal-spray process have been in the building up of worn pump rods and plungers. At one refinery, 14 per cent chromium, stainless steel plungers had been used in a hot oil pump. The rods were 60 inches long by 5-inch O.D. and 3 3/4-inch I.D. and cost new $300. These are now being made of low carbon steel tubing metallized with high carbon steel. The total cost is approximately $90. Experience indicates that the life of the metallized rod is as long or longer than the stainless steel rod. This example also illustrates one of the important advantages of metallizing. Here we have a hard surface being applied to a relatively soft ductile core, a combination of features available otherwise only by a costly heat-treating or surface-hardening process.

Table 2—Metallizing Costs Typical Breakup of Charges on a Pump Plunger 60 In. Long by 5 In. O.D.

Welder	Labor	$ 8.00
Machining	Labor	10.00
	Material	14.00
Metallizing	Labor	21.00
	Material	12.00
Grinding	Labor	25.00
		$90.00

For a hot oil pump at another refinery, new 3 3/8-inch O.D. by 1 3/4-inch I.D. by 60 inches long low chromium alloy steel plungers cost $126. These plungers were badly scored in one year's service. Three years ago, a set of these plungers, too badly scored for further use, was built up with high-carbon steel by metallizing at a total cost of $53.50 each. The re-built plungers were in perfect condition at the time of the last inspection, which represented 2 1/2 years' service. It should be mentioned that in the smaller sizes the cost of metallizing approaches that of new rods, and under certain circumstances the cost may be greater.

A slightly different technique is employed when building up a pump rod than when applying metal spray for corrosion protection. There is some difference of opinion among metallizing operators as to the best procedure to be followed. One procedure which has proved successful is described as follows:

Fig. 2 (Upper Insert)—Operator Metallizing the Surface of a Bubble Tower
Fig. 3—Metallizing a Pump Rod

First, the rod is undercut 1/16 to 3/32 inch, depending on the depth of the scoring. After undercutting the rod, 8 to 12 shallow threads per inch are cut. The surface is then thoroughly sand-blasted to render it perfectly clean and to provide the necessary roughness. This freshly prepared surface must not be handled in any way before metallizing.

The rod is next chucked in the lathe and turned at a rate which will result in a peripheral speed of roughly 30 feet per minute. The gun is supported four to five inches from the surface being built up and is moved laterally by the lathe carriage at a speed of 2 1/2 to 3 1/2 inches a minute.

First, three light passes are applied the full length of the rod. The metal speed to the gun is then increased to a maximum deposit rate of 3 to 4 pounds of metal per hour. The rod is built up to an oversize of 1/16-inch total diameter to take care of low spots. The total thickness used on an average rod will vary from 5/32 inch to 3/16 inch on the total diameter. The rod is finally ground, not machined, to finished dimensions.

It has been found to be essential when metallizing a pump rod that the work be continuous; that is, the metallizing should be done immediately after sand-blasting. Once started, it must not be left overnight or for any other appreciable length of time between coats. Any deviation from this rule will invite failure.

In spite of having worked with metallizing now for several years, we are continually being surprised with new applications that can be made and are being made. We recently had a letter from a superintendent of a power and light company in New York State who suggested the possibility of adapting the process to the rebuilding of cavitated areas on water-wheel runners at their hydroelectric plants. We had had no experience with a comparable application, but our knowledge of the process led us to believe that metallizing might be employed to good advantage. We presently discovered that another hydroelectric plant had made just such an application. In this particular case, the cavities were presumably filled by metallizing with some inexpensive material, such as low-carbon steel; and then the entire faces of the water turbine side housings were covered with 1/16-inch stainless steel. The turbine itself was likewise built up and coated with 1/32-inch stainless steel.

It might be well to mention here an application of metal spraying which, though only remotely related to the petroleum refining industry, is attracting considerable interest at the present time. Recently H. Shaw conducted some extensive experiments to determine the reliability of metal-sprayed surfaces for such major purposes as the building up of internal combustion engine crank shafts. The investigation was carried out on an assortment of actual crank shafts from 22 engines, including private-car engines, truck and bus engines and several Diesel bus engines. The crank shafts were reduced on half the journals to about 1/8 inch below normal diameter, built up by spraying with steel, and finished to size, giving a thickness of sprayed metal of about 1/16 inch. One crankshaft from each class of engine was given a thickness of sprayed metal of only 1/32 inch. Checks on the wear of the metal-sprayed journals and the ordinary journals were made over various running distances up to 15,000 miles, and in no case did the wear on the sprayed journals exceed that on the ordinary journals. The difference in thickness of metal spraying of 1/32 inch and 1/16 inch appeared to have no influence on the wear. The wear on metal-sprayed journals varied from an average of 15 per cent less than that on ordinary

journals to as little as 50 per cent of that of the plain journals in the Diesel bus engines.

A very remarkable effect of the metal-sprayed journals was on the wear of the contacting bearings, which was much less than on those contacting a plain journal. This wear was 40 per cent less on the average and 55 per cent less in the Diesel engines. To determine, if possible, the reason for this effect, seizure tests were made using hard- and soft-steel surfaces and metal-sprayed surfaces running against white-metal surfaces. It was found that, at a rubbing speed of 450 feet per minute, seizure of the white metal in contact with the sprayed-metal surfaces took place at approximately four times the load required with the ordinary steel surfaces.

COSTS

Costs per unit area of metallizing at first glance appear high; 70 to 75 cents a square foot for aluminum and $2 to $2.25 a square foot for 18–8 stainless steel. Reducing unit costs to savings to be made, as in the case of pump rods, for example, is the better way of judging whether the process can be applied economically.

CONCLUSIONS

Metal spraying has become a valuable maintenance tool and is worth serious consideration by any company continually faced with corrosion problems or doing maintenance work along other lines as suggested above. As research continues, new uses are bound to be discovered; and more dependable coatings and less expensive methods of application will be developed.

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The Construction of Step and Drive Pulleys by Arc Welding

By CARL F. ROWLEY*

I WAS confronted with the problem of making two step pulleys and two drive pulleys for a large drill press. As this press had been out of use for some time, somebody had taken parts. This press was very old, but in serviceable condition if it had been complete. Because of its age it is doubtful whether the manufacturers still had the patterns to cast these pulleys. Under these circumstances the cost would have been prohibitive. So I decided to make them of steel by the arc-welding process. At first it was necessary to make a complete layout of the different parts needed before they could be joined together. I drew up the plans, and figured out the ratio of the pulleys for a press of this size.

The parts necessary were the following. One piece of hollow shafting larger than the shaft on which it was to turn. Four steel disks to correspond to pulley faces. Four pulley faces made from rolled steel plate. One reduction gear with a hub slightly smaller than the hollow shafting. Two bushing $^1/_4$ in. larger than the hole in the hollow shafting.

The disks were flame cut from $^3/_8$-inch plate. The pulley faces were made from $^3/_8$ by 4-inch plate, rolled to proper size and welded.

The machine work consisted of boring out the center to hub size (a driving fit) and turning the outside to fit pulley faces. The hub or hollow shafting was counter bored on each end on the inside for bronze bushings and turned on one end for reduction gear. The reduction gear was then pressed on the hub and welded. Next the four steel disks were pressed into the pulley faces and welded. Then the largest pulley was forced on the hub to the proper position and welded. The three others were put on in the same manner in their proper sequence welded to each other and also to the hub. Then the bushings were pressed into the hub and bored to the proper size. Then the complete unit was slipped on the shaft on which it was to run locked and a skin cut taken on the pulley faces. The warpage of this complete unit was not more than $^1/_{16}$ of an inch on the pulley faces.

The drive pulleys and the mate to the one described were constructed in the same manner.

Fig. 1—Pulley in Process of Construction

Fig. 2—Completed Pulley

*Douglas, Arizona.

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The Corrugated Trailer Body

By GEORGE W. TELFORD*

This all-welded trailer body is known for its light weight, rugged construction which is due entirely to the simplicity of welding application to this product.

The chassis which today is of riveted construction is in the process of transformation to welding, which will further lighten the unit by the elimination of many gussets, unnecessary bolsters and the additional weight of many rivets.

There is also the possibility of a total elimination of the chassis due to the strength of an all-welded body frame.

The body frame consists of 4-inch structural steel channels which are welded to the chassis at two-foot

Fig. 1—Welding Rear End of Trailer

intervals. A pressed steel channel is then tacked to the ends of these cross-bolsters, squared, straightened, and then welded solid. A 2 x 2 x $^{3}/_{16}$-inch angle is placed $1^{3}/_{4}$ inches from the outer edge of these side rails on the top side and welded by 2-inch tacks, approximately 1 inch apart along the bottom of the angle, a shim is placed between the angle and the cross-bolsters and welded securely.

A 2 x 2 x $^{1}/_{4}$-inch angle is then formed to coincide with the bottom angle, the beveled joints are welded and temporary braces are added. This is known as the roof angle.

The rear end which is set up in a jig consists of two pressed steel posts, rear bumper and a header. It is welded solid and two 12-gage gussets are added to the back of the header to insure rigidity. (See Fig. 1.)

Two temporary posts are clamped to the front of the frame and the roof angle is then set upon them and onto the rear posts, which saves space for more pay-load. These sheets are then tacked to the floor and roof angles on the inside. (See Fig. 2.)

*The Trailer Co. of America, 31st St. and Robertson Ave., Cincinnati, Ohio.

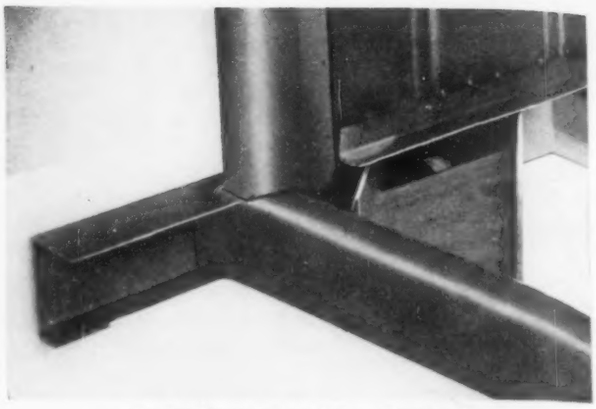


Fig. 2—Sheets Are Tacked to Floor Angles

Most trailers range from 16 feet to 30 feet in length and approximately 8 feet wide which calls for from 40 feet to 68 feet of welding top and bottom.

The bottom weld is deposited by the weave method and a $^{5}/_{32}$-inch washed rod is used. The overhead weld is made with a $^{5}/_{32}$-inch coated rod.

The upper rub rail, which protects the roof and sides from damage by trees and other obstructions encountered on the road and around the freight docks, is then tack welded to the roof angle and side sheets at the corrugations.

The roof is then set in place and securely tacked to the roof angle, the front trimmed to conform with the front or nose of the trailer. A solid water-tight weld of the lap-joint type is then applied. (See Fig. 3.)

The rear doors are made from pressed steel sills which are welded at mitered joints butted together at each of the four corners. A smooth sheet of metal is then crimped to the edges.

The hardware is made of 2 x $^{1}/_{4}$-inch strap iron, all joints being welded on latches, catches, etc.

Miscellaneous parts such as helper pads for springs, spring seats, spring tie clips, brake cylinder brackets, truss rods, prop legs, bushings, special side rails and many other small parts are made from standard steel shapes and welded in place.

Fig. 3—Welding Roof

Fig. 4

OXYACETYLENE PRODUCTION

Welding of Automatic Refrigerators*

By R. G. RODGERS† and WALTER R. CAMPBELL†

LITERALLY millions of automatic refrigerators are now in use in the United States. Hundreds of thousands of new ones are coming off production lines and into consumers' homes yearly, 250,000 of these from the Electrolux plant. But few of the millions of users have ever stopped to realize what a large part welding has played in making available to them the safe, economical, low priced piece of apparatus which is such an important factor in their comfort and good living.

At the Servel Electrolux plant we have been building refrigerators since 1927, and during that time have built up a system of production design to make the strongest and safest refrigerating unit and cabinet at highest speed and lowest cost consistent with our high-quality requirements. The development of this organized production system has a number of features which are felt to be unusual in their results and the history of how they have contributed to the finished plan is of interest.

First let us consider why we use torch welding. To do this we should start with the cabinet.

In the fabrication of refrigerators we are confronted with the standard problem of all manufacturers. The first is floor space needed for the job and equipment; next adaptability of tools to other jobs; next initial investment, and last but not least, cost of manufacture. For this reason we use oxyacetylene not only in the fabrication of our unit, but also in the making of our cabinet shell and liner. Our cabinet shell is of one-piece construction. This is for strength, better sealing and also does away with gaskets at seams.

First a large sheet of steel is blanked, pierced and flange formed. In the blanking a development is formed in the corner so that after the shell is folded over the fixture it will leave four small slots in the corner, approximately three inches long. These corners are then welded on a water-cooled fixture by the oxyacetylene torch and rod. This is followed by metal finishing to obtain a smooth surface. These fixtures are very small and the whole set-up for welding the corners on a 1000-per-day basis is probably 8 ft. x 10 ft. in size. This is a saving in floor space. Also if this job is abandoned, we can use torches and hydraulics on other jobs. The initial investment is small when computed against presses or electric seam welders. Also the manufacturing cost per unit is very much in line.

This is the basis on which we set up our jobs, and on this one we are sure oxyacetylene welding saves money. Another place in our cabinet where we use torch welding to advantage and save money is in the fabrication of our liner, or the box that forms the inside of our refrigerator. This is to be coated with porcelain after being fabricated in the sheet metal department, and therefore must be handled in a way to cut down warpage in the furnace, as well as make a good product to be porcelained and hold its shape.

Some plants use electric seam welding for this operation and claim it is much cheaper. With our set-up for other welding, this does not prove out in our plant. We have checked this operation time and time again and find in our case oxyacetylene welding to be the cheapest.

Our fixture costs for the welding of liners is not nearly as expensive as for seam welding and this amounts to a great sum of money when you have a large number of different models. Also the maintenance on our method is very small in comparison with electrical set-up.

All the other savings such as floor space and equipment cost in the obsolescence of equipment follow the same trend as that in use on the shell.

We have numerous other small jobs in our cabinet division where we use torch welding to a great advantage. This does not mean that we do not use electric welding, but whenever we have a welding job both methods are checked for complete cost, and the best method is selected.

Next let us tackle the unit of this refrigerator. As you know we do not use a compressor in our refrigerator, we employ the absorption type of unit actuated by heat. This calls for the use of a large amount of tubing and the use of torch welding.

The Electrolux refrigerator, more than any other, depends on welding, and in fact it might be said that to build the Electrolux would be almost impossible were it not for oxyacetylene welding.

A description of the major manufacturing operations will show but a few steps where welding is not concerned. As an introduction, however, a description of the unit will make quite understandable the reasons for fabrication by welding. Each unit consists essentially of seven parts, known as the generator, liquid heat exchanger, absorber, condenser, rectifier, gas heat exchanger and evaporator.

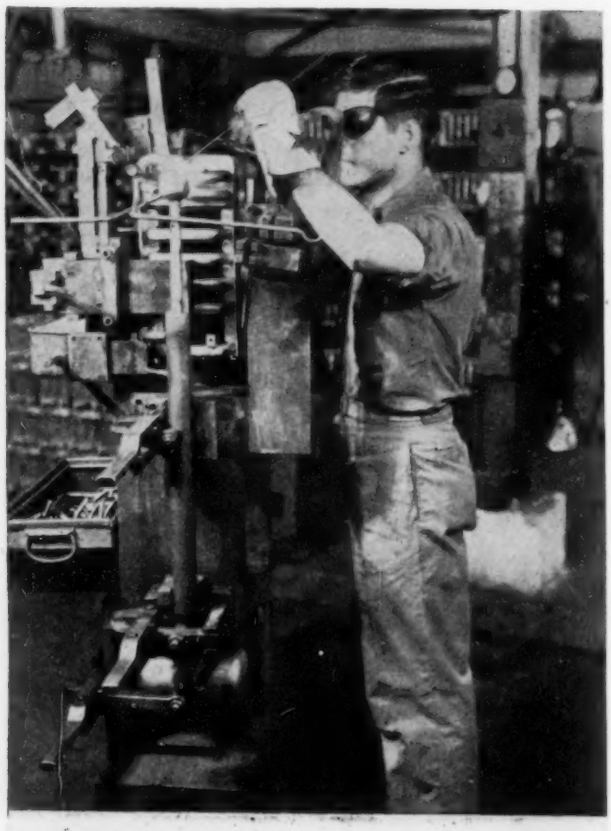
The first major unit assembly consists of the absorber heat exchanger and evaporator of chilling unit, a mass of tubing ranging from $2^1/_4$ inches to $^5/_{16}$ inches in diameter, and from 12 to 17 gage in various forms and connections welded together.

The absorber shell is a $4^3/_4$-inch diameter two-piece cold-drawn shell welded together by an automatic machine with continuous wire feed; the pressure chamber is made up of a single $2^1/_2$-inch diameter tube with caps

* Paper presented at the 40th Annual Convention, International Acetylene Association, Milwaukee, Wisconsin, April 10, 11 and 12, 1940.

† Works Manager and Superintendent, Respectively, of Electrolux Division, Servel, Inc., Evansville, Indiana.

Fig. 1—Unit First Major Sub-Assembly Tack Welding



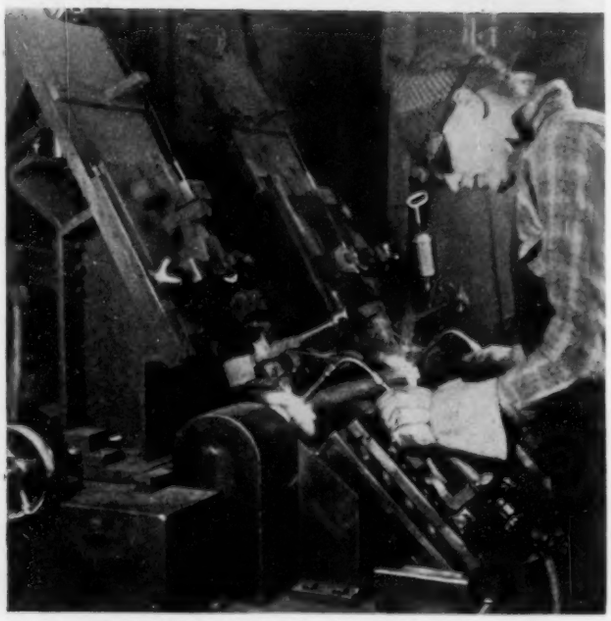


Fig. 2—Automatic Oxyacetylene Welding Machine

welded on either end. This is done by an automatic machine by which, by the use of two blowpipes, the caps are welded on simultaneously. As in the former case continuous wire feed is used and the operator merely loads and unloads the machine.

The design of the unit as shown in the accompanying illustration consists almost entirely of tubing and drawn shells of various diameters. The design of the unit is such that it will stand a pressure or over 3000 pounds without bursting. The excessive strength is not needed for the normal operation of the unit, but is needed to make the high pressure leak test, used in the factory, safely.

There are 116 individual welds in the medium-size unit, making a total of approximately 235 inches of welding in metal, ranging from 17 to 12 gage. Most of the parts are made from seamless steel tubing and deep drawn steel shells.

To give some idea of its size, the largest unit made for domestic purpose fits into a space of 6.8 cu. ft., $6^1/_2$ inches in depth, $36^1/_2$ inches in width and $53^1/_2$ inches over-all length.

MATERIALS, APPARATUS AND JIGS

The flow sheet below summarizes the essential steps in the manufacture of the unit:

Raw Materials—Reduce tubing, wash, bright anneal, cut to length, bend, form, drill or otherwise fabricate, clean, sandblast.
Welding.
Leak Test and Repair.
Assemble into Insulation Box and Charge Unit.
Calorimetric Test for Capacity.
Final Assembly of Accessories to Unit.
Installation in Cabinet.

In view of the fact that the unit must have long life, the utmost care must be exercised in the selection of raw materials used, and in its fabrication. The tubing and steel used, fall within the following analysis:

Carbon	0.16 Max.
Manganese	0.25–0.60 Max.
Phosphorus	0.05 Max.
Sulphur	0.05 Max.
Silicon	0.20 Max.
Copper	0.15 Max.

The analysis was set up to give a good welding steel soft enough to be fabricated into the intricate bends and coils required.

The tubing is bright annealed in an electric furnace to eliminate scale formation to a maximum tensile strength of 51,000 lb./sq. in. and hardness range of 55 to 65 Rockwell B scale.

The welding rod used falls within the AMERICAN WELDING SOCIETY's specifications No. G-1*A* as regards analysis, but the analysis alone is not sufficient to define a suitable rod. Freedom from inclusions, gas bubbles and scale is also necessary to get leak-proof welds and weld metal that can be porcelain-enameled without trouble or staining.

The acetylene for welding is supplied by two low-pressure non-automatic acetylene generators, each with a carbide capacity of 500 lb., and with an hourly rating of 3000 cu. ft. of acetylene. The generated acetylene is not turned directly into the supply line, as is done when an automatic feed generator is used, but first conveyed to a large storage holder with a capacity of 2000 cu. ft. of acetylene. The feeding of the carbide to the generator can be started or stopped as desired. As the time required for charging each generator is less than 20 minutes, there is always ample time to replenish the supply in the storage holder to adequately supply the shop demand, assuring an uninterrupted supply at all times. This is an important feature where a conveyor system is used, because a hold-up would cause serious disruption in production.

On account of our large consumption it has been found possible to supply oxygen to our plant in liquid form. It is evaporated from the liquid into gas and piped to the welding stations. The oxygen pressure is held to approximately 27 lb./sq. in., and the acetylene is about 14 inch water column pressure, equivalent to 9 oz. gage pressure. Close attention was given to the proper design and erection of the new oxygen and acetylene piping systems, so there would be no cause for interrupted service from this score. In making these installations of oxygen and acetylene supply lines, valuable assistance was rendered by the engineers of the company supplying our oxygen.

After cutting operations have been performed on the rough stock, consisting mostly of tubing, any forming necessary is done with the aid of special bending machinery. The necessary holes are drilled or punched, all burrs carefully removed and the cooling fins added. After the parts are thoroughly washed and steamed to remove all grease, they are then put through a sandblast operation, using steel grit as the abrasive agent, and are then ready for the Welding Department.

When two pieces of tubing are welded together, they are always formed or machined to fit closely so that a minimum of bridging over is required of the welder. It is found that this minimizes leaks; also, where possible, the unit is designed to make it unnecessary to make one weld overlap the second.

As positioning members in jigs, heavy fixtures into which the welder cannot force a piece of incorrect dimensions are used, and all parts are tack welded together in the correct relationship in these, and taken out for finish welding.

Tacking jigs are designed for ease in loading and of ample strength to rigidly hold the parts in the exact position for welding.

A very good welding rod is essential in the welding of light gage tubing. It must be free of all dirt, rust, grease or other substance which might form harmful oxides during the welding process. It must not thin out and run too freely when flowed into the weld. We use two sizes of welding rod, $^1/_{16}$ inch and $^3/_{32}$ inch.

OPERATOR TRAINING AND WELDING METHODS

Since about 30 per cent of the entire Production Department of the Electrolux Unit Division operate welding torches, about 400 operators in all, the provision for keeping this part of our staff efficient is an important project. In the beginning, to make possible replacement of trained welders in this department and to provide for constantly growing production operations, it was found very valuable to operate a welding school continuously as an adjunct to the factory. Some experienced welders were obtained locally, but as a rule it was found more satisfactory to train men who have never done welding before. The capability of the apprentice welder, when first put on a production job, can very quickly be determined by the leak test, in which all welds are examined with soapy water while the unit is under the 850 lb./sq. in. of air pressure. This is very much greater than the operating pressure, but it only amounts to about a third of the bursting strength of the weakest part of the system. This test is an excellent barometer of the capabilities of all operators and apprentices. The more experienced welder will have on an average about 3 per cent of leaks reported back to him. The apprentice welder, when first put on production work, will quite naturally have a much larger percentage of leaks. Each operator is assigned to a particular weld, and it is a very easy matter to keep a complete record of his work, which is done by the leak testers, who record the particular welds that are found leaking.

By this method, the welders are all inclined to do their best work. Women quickly learn the technique of welding. Many have been trained for the lighter and more tedious jobs, and on this class of work they have worked out more satisfactorily than the male welders. In training welders, bridging is taught, rather than penetration. This is to prevent the welders from melting through small pipes and closing or partially closing these off, thus interfering with the operation of the unit. Welders are first taught on scrap plate material. They are then put on simple sub-assembly welds and given more complicated welds as they become more adapt. The best welders are used for repairing leaks found in welds previously made.

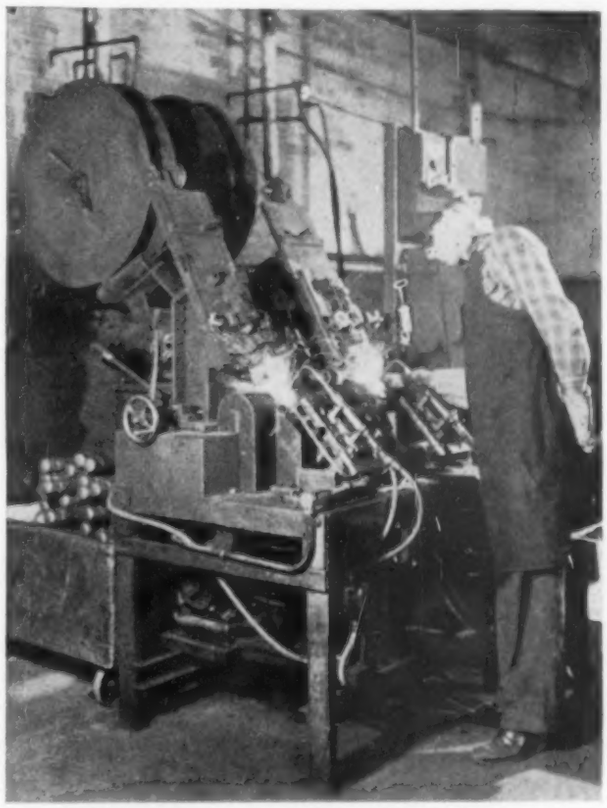


Fig. 3—Automatic Oxyacetylene Welding Machine

In 1938 there was established in Evansville, Indiana, the Mechanic Arts school. This vocational school has a fine up-to-the-minute welding set-up. Our future source of supply of welders is assured.

In this present set-up the school furnishes and maintains the welding equipment and pays the instructor. The students must pay a welding gas and registration fee of $8.00 which represents about one-half of the cost. The balance of the cost includes welding gas, welding rod and scrap metal to practice on, which is furnished by our company as a gift or donation to the trade school. There is no restriction as to who can or shall attend the classes. The instructor and vocational director, however, do discourage any from taking the course who do not show definite promise of eventually remaining and progressing in this work. The school encourages young alert men who have just finished high school to take this course. When these men are given jobs they usually stay, inasmuch as it is their first and the only job in

which they have any training. Since we have started employing this type of men for welders our labor turnover has been reduced to practically nothing. Any man, willing and ambitious enough to spend a little money and time to train himself, will make a good employee in any type of work.

PRODUCTION METHODS—WELDING ON CONVEYORS

Frequent expansions of manufacturing facilities have been made since this refrigerator was first placed on the market, and toward the end of 1930 the output had increased to an extent that manufacturing by a continuous conveyor was justified. So far as was known, welding had never been used for the fabrication of metal parts while moving on a conveyor. Nevertheless, after consultation with various engineers, it was decided the plan was quite feasible, so the entire manufacturing process was coordinated to the new scheme, and a conveyor was placed in operation. All this was completed with but little disturbance to the manufacturing schedule, particularly since the change-over was made during the slack period of our yearly production cycle. The flexibility of welding as a manufacturing tool has been clearly demonstrated in all previous expansions of the plant. It was merely to train new welders, which was done in the school operated in conjunction with the Welding Department, provide new welding stations, which are relatively inexpensive, and quickly install and provide other miscellaneous equipment, such as jigs which were readily made in the plant.

It can be said that the benefits which have resulted from the adoption of the conveyor system of production have been ample repayment for the expense of the change-over and the investment in new equipment. Lost motion in handling and stacking the various subassemblies and completed units, has been almost entirely eliminated, and the welding efficiency has been greatly increased. There has also been a decline in the percentage of leaks even though the welding is done while the work is moving. It has been found that the movement of the conveyor is not detrimental to quality work. However, the operation of the conveyor should be smooth and without any irregular motion. The most gratifying feature to the management, however, has been that the oxyacetylene welding process was so readily adapted to the conveyor system, and that production could thus be increased by 50 per cent with but a 20 per cent increase in the number of operators.

The Welding Department is laid out with the subassembly benches and fixtures for tacking the parts together at right angles to the conveyor line. The conveyor is designed to travel along the line of production at a rate of about 7 feet per minute, 458 feet per hour for maximum production. At every 6 feet along the conveyor chain is a special swivel hanger for holding the work. Consequently, one unit about every 46 seconds,

Fig. 4—Liner Welding

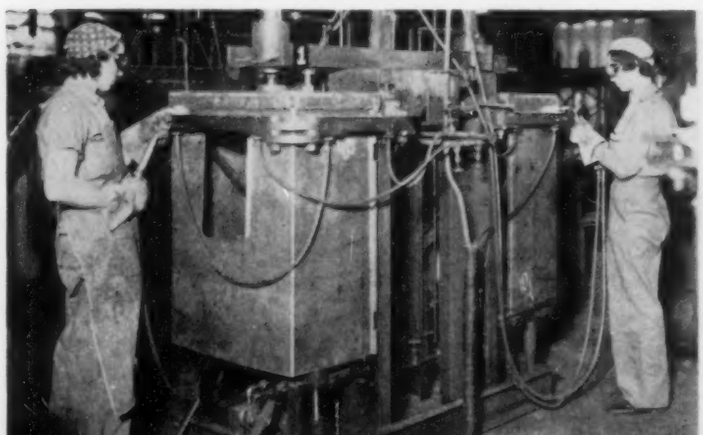
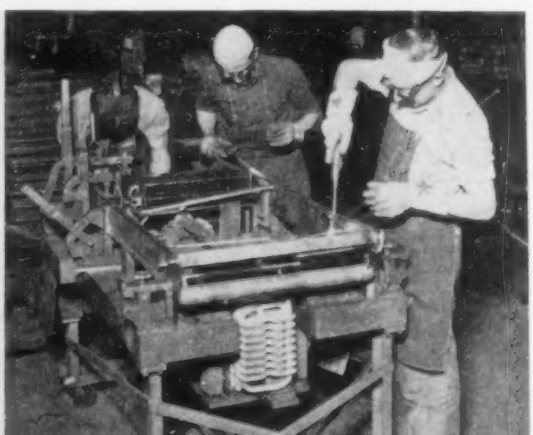


Fig. 5—Unit Final Assembly Tack Welding in Fixture



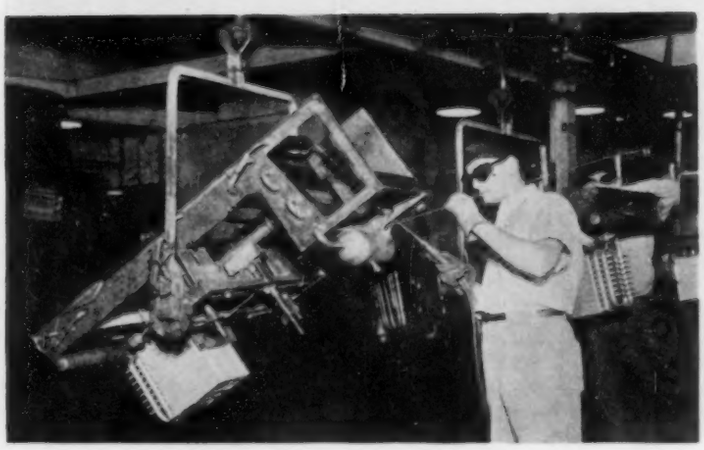


Fig. 6—Unit Final Assembly Welding on Conveyor

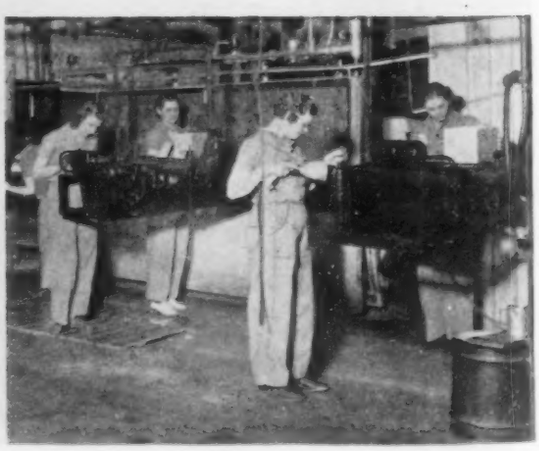


Fig. 7—Leak Testing Using Soap Solution

Fig. 8—Final Leak Testing Using Phenolphthalein Paper

or 78 units per hour, can be turned out when desired. The time needed to execute a weld varies according to its length, position and other factors, but in general welding operators make from 60 to 100 joints per hour.

The first part of the unit to be placed on the conveyor, after assembly by tack welding, is the evaporator and the gas heat exchanger assembly. A sufficient number of operators are assigned to welding on this part so that each can finish welding his weld easily in the allotted time. Welding tips are specified for the weld to be made, and constant oxygen pressure and low constant pressure acetylene assure the foreman that the welder uses the correct size flame.

This assembly rides to a point along the line where several first major sub-assembly tacking fixtures are located. They are then all removed from the conveyor, for tack welding into a sub-assembly, and a tack-welded sub-assembly put in its place, and the finish welding divided among the various operators and completed as before. At a point where these operations have been completed, are located the sub-assembly lines of the condenser and side rail and rectifier assembly, and the generator and liquid heat exchanger assembly and the absorber assembly.

These lines run parallel to the conveyor and ride to a point where the conveyor makes a U-loop around the second, or final assembly welding fixtures, where they are taken off for tacking, and the operation repeated as before, by placing back on the conveyor for a finish welding. Following this the unit is ready for the leak test and repair.

TESTING PROCEDURE

The tests which each unit undergoes are extensive but we have found that they are necessary to maintain perfection in our product.

The first operation is a pressure rupture test; the unit is charged with 1000 pounds air pressure. The purpose of this test is to determine if any weak or split tubes are in the unit. The unit is then charged with 850 lb. air pressure and tested for leaks using a liquid soap solution which is brushed or poured on, coating the welds with a film of soap. The leaks show up with bubbles or a white foam and are marked with wax crayon. The air is then released and the weld repaired. This is done by re-welding about half of the joint and adding more filler rod. An average of about three leaks on each unit is found on this first test. The unit is charged with air, tested and repaired, if necessary, five different times and then given an inspection check test.

After the unit leaves the welding department it is painted and the paint baked on. It is then charged with air and again tested. The unit is warm when tested and the joints expanded. The leaks found are very small and welds must be examined very closely. Some of these show up with foam no larger than a pinhead after several minutes' watching.

Before the refrigerants are charged in, however, all parts of the unit from which it is desirable to prevent heat loss during operation, are enclosed by steel casing, packed with mineral wool insulation material. The unit is then evacuated and charged with the required amounts of aqua ammonia, water and hydrogen gas, while moving on the conveyor.

After this operation, the unit leaves the conveyor and is placed on a stationary test rack where it is given a calorimetric test of several hours' duration, for refrigerating capacity. The test is carried out by introducing a definite amount of heat into the boiler and reading the temperature of the refrigerating compartment or evaporator, when working under a known heat load. In order to obtain the extreme conditions encountered in service and to maintain uniformity, all units are capacity tested in a hot room held at exactly 100° F.

After the unit is in operation it is again tested for leaks. The test here is entirely different from all previous tests. The welds are wrapped with moistened paper previously treated with a chemical that reacts in the presence of ammonia. Any ammonia vapor, regardless of how small, seeping through a weld turns the white paper a reddish pink color at the point of the leak. These leaks are so small that many of them cannot be detected when the unit is discharged and checked again with high-pressure air and soap solution. All units which fail to make the load-capacity test due to having a plugged or partially plugged weld in the system, are discharged and the solution washed out, and the welded joint cut out and replaced. We have been able to cut down the unit rejects from bad welds at this point to less than $^1/_2$ of 1 per cent.

As a further check against the manufacturing calorimetric test, a Control Laboratory is operated as an adjunct to the factory, and a certain percentage of the units are picked at random from the test lines and given a very sensitive test in this department. The Control Laboratory also assists the manufacturing and inspection departments in finding the defects causing a particular unit or batch of units to be rejected on the calorimetric or hot room test.

After this test the units are placed on another conveyor for final assembly where they are equipped with all gas controls and final touch-up.

After a general inspection, the unit is placed on an overhead conveyor carrying it to the cabinet department, where it is removed and installed in the cabinet on another conveyor.

LOW-TEMPERATURE BRAZING with Silver Alloys*

By ROBERT H. LEACH†

IT IS doubtful whether many persons realize the extent to which silver alloys are used today in brazing both ferrous and non-ferrous metals and alloys. The quantities used are small in comparison with base-metal brazing alloys, but the amount of joining that is being done with silver brazing alloys is impressive, because the best results are obtained when the joints are closely fitted and a much smaller quantity of the alloy is used than is the case with the V-joints or heavy filleted joints which are common to base-metal brazing or soldering.

Silver brazing alloys have been used for centuries by metal workers, particularly in the silverware industry and for making joints in those cases where strength and resistance to shock were required such as joining band saws, shrouds and lacing wire for turbine blades, and in the fabrication of equipment where appearance as well as strength was important. They usually contained varying percentages of silver, copper and zinc and were called silver solders. These compositions had melting points from 1300 to 1600° F. depending upon the proportions of the different metals or a range below that of base-metal brazing alloys or copper welding rods which required from 1600 to 2000° F.

About fifteen years ago the industrial use began to show considerable increase and the interest was sufficient to cause the American Society for Testing Materials to draw up specifications for a group of standard alloys. These standard specifications were finally accepted and published in 1929 and are given in Table 1.

Table 1—Standard Alloys Specifications

Grade No.	Silver, %	Copper, %	Zinc, %	Cadmium, %	Impurities, Max. %	Melt. Point, ° F.	Flow Point, ° F.	Color
1	10	52	38	[a]	0.15	1510	1600	Yellow
2	20	45	35	[a]	0.15	1430	1500	Yellow
3	20	45	30	5	0.15	1430	1500	Yellow
4	45	30	25	Nil	0.15	1250	1370	Nearly white
5	50	34	16	Nil	0.15	1280	1425	Nearly white
6	65	20	15	Nil	0.15	1280	1325	White
7	70	20	10	Nil	0.15	1335	1390	White
8	80	16	4	Nil	0.15	1360	1460	White

[a] The addition not to exceed 0.50 per cent of cadmium to assist in fabricating Grades Nos. 1 and 2 shall not be considered as a harmful impurity.

The alloys are called silver solders in these specifications, and although this name is used widely, it is believed by many that the name, silver brazing alloy, is preferable because the term solder is likely to be taken as referring to soft solders, which are used in large quantities in industry and melt at approximately 400° F. Brazing, on the other hand, suggests higher melting temperatures than soft solders and greater strength of joints which are characteristics of these silver brazing alloys.

The eight grades given in Table 1 were selected after a large amount of testing had been done to determine the range of compositions required to meet the different industrial requirements. The ternary diagram of the flow points of silver, copper and zinc alloys is shown in Fig. 1 and it is evident from a study of the diagram that without some attempt at standardization, there would be a tendency for the production of a large number of different compositions with no material benefit to the consumer. In fact, one of the principal reasons for setting up these standards was to eliminate many compositions which had accumulated over a long period of time, and varied so slightly from each other that there was no justification in making all of them.

The question that immediately arises is why the use of these more expensive alloys should show such a large increase. The answer is twofold: first, the demand on the part of those industries engaged in fabricating articles and equipment from sheet metal and tubing, for better and quicker methods of joining; and second, the comparatively low melting points of these alloys, their free-flowing properties and the strength of joint made with them.

As might be expected, the increase in the use of the standard alloys encouraged extensive research and the development of other silver alloys for brazing. There was a demand for alloys with even lower melting points without sacrificing the strength or the free-flowing properties of the standard alloys. Moreover, there are certain corrosive conditions where the presence of zinc might be harmful, and in other cases copper might be undesirable. The result has been that we have available today silver brazing alloys, in which other metals, such as cadmium, manganese, tin, nickel and phosphorus, are used to give special properties.

Some of these alloys have been patented but they are used to such an extent both in this country and foreign countries, that any article dealing with the development of silver alloy brazing would not be complete without mention of the characteristics of some of them. The silver copper eutetic which contains 72% of silver and 28% of copper melts at 1435° F. and is used when zinc in the alloy would give trouble. Alloys containing silver, copper, nanganese and those with a further addition of nickel and silicon are used for similar purposes. Zinc or Zinc and cadmium combined with relatively high percentages of silver provide a series of alloys that melt at temperatures between 1300° and 1400° F., have a white color and are used for those conditions where copper would be objectionable. A patented alloy containing silver, copper, zinc and cadmium which flows freely at 1175° F. is used extensively for joining both ferrous and

* Paper presented at the 40th Annual Convention, International Acetylene Association, Milwaukee, Wisconsin, April 10, 11 and 12, 1940.

† Vice-President, Handy and Harman, Bridgeport, Connecticut.

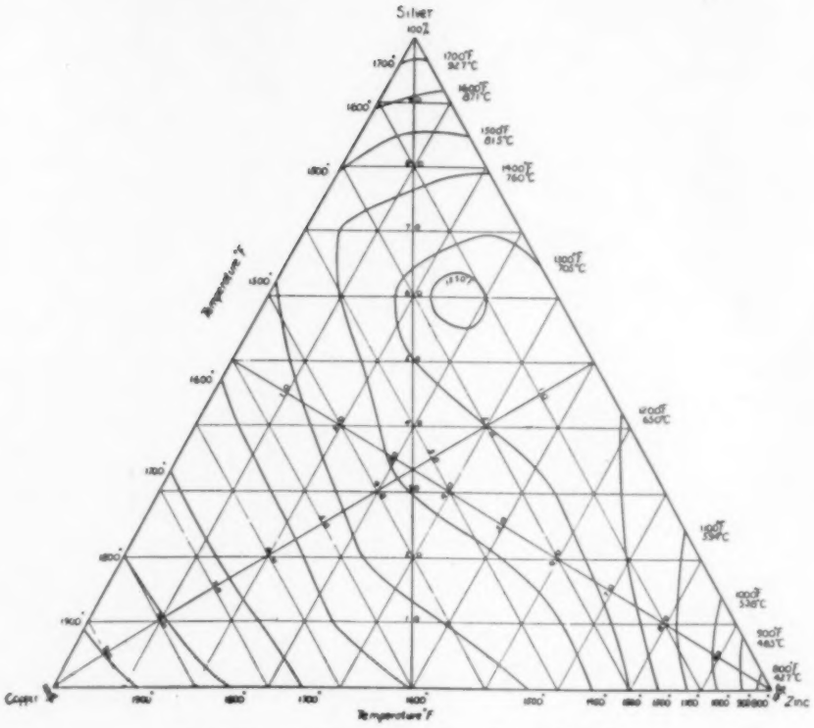


Fig. 1—Liquidus Diagram of Silver—Copper-Zinc Alloys

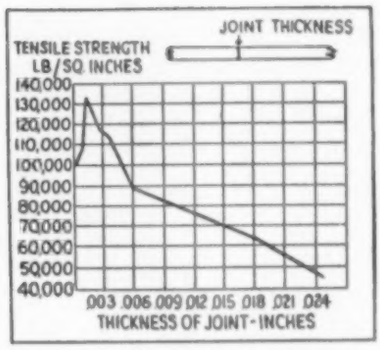


Fig. 2.—Relation of Joint Thickness to Tensile Strength Based Upon Butt Joints of Stainless Steel to Stainless Steel

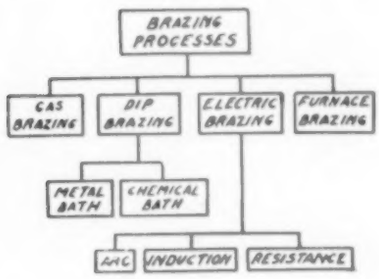


Fig. 3

non-ferrous metals and alloys, because it flows very freely at this temperature and makes strong joints. Another patented alloy contains silver, copper and phosphorus and flows freely at 1300° F. The phosphorus makes the alloy self-fluxing to a considerable degree and it is used with copper and copper-base alloys, but it is not recommended for steel or iron because of the brittle phosphide of iron that is produced in the joint.

SELECTION OF GRADE AND FORM OF BRAZING ALLOY

There is no definite rule to follow in selecting the grade of silver brazing alloy as several different factors have to be considered, among which are: metals to be joined, corrosion conditions, type of joint and stresses that may be applied.

In the standard silver-copper-zinc series given in Table 1, the silver content will run from 10 to 80% and those with the lower percentages of silver have the highest melting points and contain relatively high percentages of zinc. These low-grade alloys cost less per unit but it must be remembered that much of the advantage from the use of a silver brazing alloy is lost, because of the high temperatures required to melt them. It should also be emphasized that the lower first cost of the alloy does not mean that the total cost of making the joint will be less. By taking proper care in the design and fitting of the joint, such a small amount of alloy is used, that the saving in time and fuel will more than offset the higher cost of a more expensive alloy with lower melting point. There is also a much greater margin of safety from damage to the metals when the alloys with lower melting points are used.

As far as melting point is concerned a silver-copper-zinc alloy containing 10% silver does not have any material advantage over the common brazing or spelter alloys, but it contains about 12% less zinc and as it is malleable and ductile, it can be rolled into thin strips and drawn into fine wire. It is sometimes used when quenching at temperatures about 1300° F. is done after joining, and with copper and copper-base alloys when first cost seems to be the controlling factor, and it is felt that the heating will not cause excessive grain growth or other damage.

The 20% silver alloy in this group is used on copper and copper-base alloys, also on steel and dissimilar metals. It has a yellow color and as it flows freely at 1500° F. it can be used for brazing extruded bronze when reasonable care is taken in heating the joint.

With 30% of silver and above we obtain more benefit from the low melting temperatures due to the silver content and we can use a lower percentage of zinc. Those alloys containing from 40 to 50% of silver and from 25 to 16% zinc are probably the most widely used of the silver-copper-zinc group. They are used on ferrous and non-ferrous metals and alloys, and melt at temperatures around 1400° F. depending upon the exact composition used. An alloy containing 50% silver, 34% copper and 16% zinc is a standard that has become generally accepted in place of a number of other alloys of approximately this composition that were made before the A. S. T. M. standards were established.

The alloys in this series which have the lowest melting points contain from 60 to 65% silver and are white in color. Silversmiths use these grades and with 15% zinc they melt at 1325° F. and are used in other industries for joining small parts and light weight tubing and sheet.

When even greater ductility is required, the silver can be further increased and the zinc lowered and an alloy containing 80% silver, 15% copper and 4% of zinc is used for joining copper rods that are to be drawn into fine wire and also for making trolley wire.

Silver brazing alloys have a higher electrical conductivity than base-metal brazing alloys and their use is therefore particularly desirable for brazing parts of electrical apparatus where the highest conductivity is required. Zinc tends to lower the conductivity and the

silver-copper eutectic previously mentioned has about 70% of the conductivity of copper.

Tests by Reed and Edelson showed that with lap joints having a lap one and one-half times the thickness of the copper bar which was joined, the resistance was less than that of the copper bar, and with butt joints the resistance was only increased slightly. The alloy used in these tests contained 50% silver, 34% copper and 16% zinc and by using an alloy with higher percentage of silver and low zinc the resistance would be less.

Any of the standard silver brazing alloys are resistant to most of the common types of corrosion. When unusual conditions have to be met it is desirable to make up specimens and subject them to the actual conditions of use in order to determine the best alloy. Galvanic corrosion is a problem but as it is generally in proportion to the areas exposed to attack, a cathodic joining alloy would give the best result. Silver alloys with high percentages of silver are cathodic to many metals and alloys used to resist corrosive conditions and they are therefore satisfactory for use under such conditions. For example, these high-grade silver alloys are cathodic to monel metal and stainless steel under many corrosive conditions for which these metals are used. They should not be used, however, for joining stainless steel when the joints are likely to be attacked by nitric acid.

In addition to the standard silver alloys, the engineer has a further selection from the proprietary alloys that have been developed and the two that were described in previous paragraphs are suitable for a wide variety of applications. Their low melting points have made them very acceptable because of the speed at which joints can be made and the large factor of safety against damage from overheating.

The question of color match with different metals and alloys is often raised. Those silver brazing alloys with low percentages of silver are yellow and the color becomes whiter as the silver is increased. Alloys without any copper and high silver are the whitest, but the band of brazing alloy which is visible in a properly fitted joint is so narrow that any slight difference in color is generally a negligible factor.

Having selected the grade of alloy, the question of the form that is best suited for any particular application is most important. The malleability and ductility of silver brazing alloys allow them to be produced in any form that will be most convenient and economical to use.

There is a rapidly growing use of inserts of these alloys because by preplacing them before heating the following advantages are obtained:

1. Control of the amount of alloy used, thus eliminating waste.
2. Better assurance that the alloy will be properly distributed over the joint surfaces and all parts will be wetted.
3. The appearance of the alloy at the edge of the joint is a good indicator that the joint has been heated sufficiently to insure a good bond.
4. In furnace or salt bath heating, inserts are necessary, and it is possible to make up assemblies having a large number of joints that can be heated at the same time.
5. When the heating is done with torches the workman can give his whole attention to evenly applying the flame and careful control of temperature.
6. Neatness of joints and no spills of the brazing alloy on the surface away from the joint.

Inserts may be thin sheets, washers and rings of either round or rectangular wire. Filings or powdered silver brazing alloy can be spread along the joint.

A thin layer of the alloy can be flushed over the joint surface of one of the members before assembling.

The size of wire or strip selected when the workman has to feed it into the joint is not always given the attention it deserves. If wire or sheet of too large a cross section is used, there is likely to be a waste of the alloy, and if it is too small the workman is inconvenienced by having to feed in too great a length. Care in choosing the right size will result in lowering costs and making better and neater joints.

FITTING, CLEANING AND ASSEMBLING

Procedures for using silver brazing alloys are given in detail in the different papers listed at the end of this paper, and only a brief summary will be attempted.

Silver brazing alloys flow freely into narrow openings, and clearances of a few thousandths of an inch should be maintained to produce the strongest joints. Figure 2 illustrates the effect of joint clearance on strength. The surfaces of the joint should be clean, and free from all grease, dirt and oxide scale.

The important point to keep in mind is that we must have a clean, nascent metal surface, that will be evenly wet by the brazing alloy. Any film that prevents the wetting of the joint surfaces will prevent a strong bond being made. After all grease has been removed the surface can be cleaned with emery cloth or pickled with a suitable solution to remove any scale or highly polished surface that has resulted from rolling or drawing. Webber, in an excellent paper* on "Electric Furnace Brazing," explains fully the difficulties of trying to get brazing alloys to flow on highly polished surfaces and a slight roughening by either mechanical or chemical means is a great help to good bonding.

When joining flat members either with lap or butt joints, it is desirable to grind or machine the surfaces of the joint so that they may be held parallel and equidistant from each other. If thin sheet inserts are used the parts should be clamped together with enough pressure to hold them firmly together after the alloy has melted.

When tubular members are joined this pressure cannot be applied and there is nothing to break down the surface tension of the molten alloy and cause it to flow except gravity and capillary action. It is in joints of this type that the preparation of the joint surfaces must be given particular attention in order that the molten alloy will wet them and spread evenly. If the space is too great the capillary action will not be sufficient to cause proper spreading and if the surface is not wet with the alloy this action is also ineffective. Unless care is taken to prepare and fit joints of this type, parts of the surface may become wetted and the brazing alloy will flow through in irregular channels and even form a fillet at both ends of the joint, thus giving the appearance of a good bond when actually only a very small portion of the joint surfaces are bonded together.

After the members have been fitted and cleaned properly, the joint surfaces should be protected with a film of flux. This flux must be fluid and chemically active at the melting point of the brazing alloy and be spread over the entire surface. It is also advisable to protect the brazing alloy with flux when it is fed into the joint.

Borax or combinations of borax and boric acid are used, but specially prepared fluxes that are fluid and active at lower temperatures are available, and are preferred for the lower melting-point alloys. These proprietary fluxes are composed of chemicals that dissolve refractory

* *The Iron Age*, Nov. 3, 1938.

oxides readily, and should be used with stainless steels. A flux that has been particularly successful for use with silver brazing alloys is supplied in paste form and can be brushed along the joint to insure proper coverage.

Jigs should be provided to hold the parts in proper relation during heating. Some types of assemblies require little support but the members should be held firmly together so that no strain will come on the joint until it has cooled to a temperature well below the melting point of the brazing alloy. When the necessary care is taken in supporting the joint members, the workman is free to devote all of his attention to applying the torch flame and he can do much better work in less time.

HEATING

There are several different methods of supplying the heat necessary for brazing, and the chart given in Fig. 3 was adopted by the AMERICAN WELDING SOCIETY.

These different methods of heating are also described more fully in the appended list of papers and only gas brazing will be discussed to any extent at this time.

Gas brazing includes all combinations of torch brazing such as oxyacetylene, oxyhydrogen, oxygen and city gas, natural gas and gases such as butane or propane; also air acetylene and air with other gases mentioned.

The air-gas and air-acetylene torches will give satisfactory results with small parts and the large torches or those with multiple flames may be used on fairly large work. However, the tendency to use an oxidizing flame in order to heat the work quickly with air torches is one of their disadvantages for use with silver brazing alloys.

Fortunately we have the oxyacetylene torch which has been highly perfected and can be obtained in a great variety of sizes and types. It is probably the most widely used torch where rapid heating is an advantage, and it has great flexibility in the hands of a skilled operator.

Because of the high temperature of the oxyacetylene flame there is no need for the operator to be tempted to run it on the oxidizing side, and he can obtain all the heat required and still keep to the softer flame a little on the reducing side of neutral. It might be compared with the modern eight-cylinder automobile engine, and the air-gas torch with the old two-cylinder engine of years ago. There may be some basis for the argument that an unskilled operator can do less damage with an air-gas torch, but what we are really concerned with when brazing with silver alloys is an effective means for quickly and evenly heating the joint with a neutral or reducing flame. Of course, care must be taken in the use of the oxyacetylene torch to keep it in motion and not let it play too long on one spot, but an intelligent workman will soon master the proper technique and he then has an instrument that will enable him to control the heating most efficiently.

Large units can be installed for supplying the oxygen and acetylene and portable small units are made for small plants or field work. Servicing and supplies can be obtained quickly in all parts of the country.

The manufacturers of oxyacetylene torches are always willing to cooperate in the design of special tips or torches with multiple tips to meet any specific requirements.

They can be used for such extreme conditions of heating as the silver alloy brazing of fine wires in Fourdinier screens on the one hand to brazing flange joints 42 inches in diameter on the other.

Figure 4 shows a two-flame No. 10 tip heating a large flange assembly and Fig. 5 a small multiflame torch for small parts.

In order to obtain the full benefit from these low temperature silver brazing alloys the workman should be trained to observe the rate at which different metals become heated to the brazing temperature and give particular attention to relative mass of each of the members that are being brazed. Metals of high heat conductivity such as copper should be preheated some distance from the joint and if there is much difference in the size of the parts then the one with largest cross section should be given the most heat.

Unless inserts are used, the joint surfaces should be heated to a temperature at which the brazing alloy will flow freely before attempting to feed the alloy into the joint. Although it is not advisable to keep the torch flame on the molten alloy and the expression, "let the heat in the joint melt the alloy," is often used, a skilled workman can take advantage of the heat of the flame to

Fig. 4—A Two-Flame Tip for Heating a Large Flange Assembly

Fig. 5—Small Multiflame Torch for Small Parts

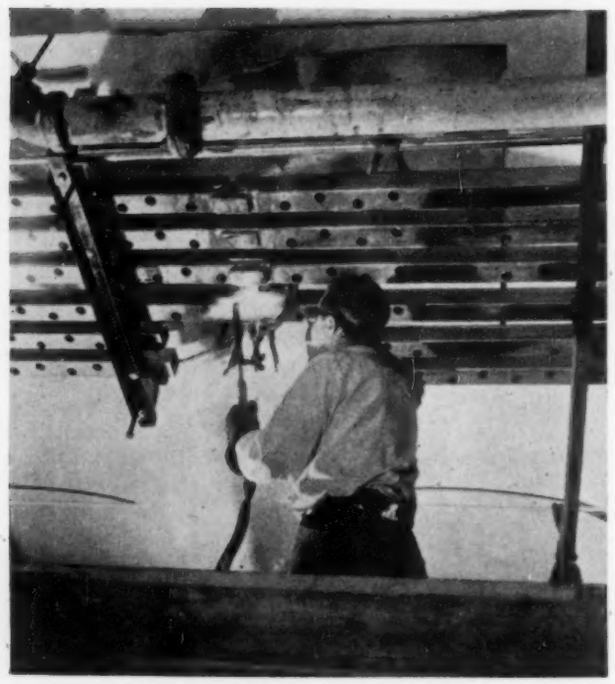


Fig. 6—A Bus Bar Assembly Being Brazed

melt the alloy, which then flows quickly into the joint. In all cases, however, the joint surfaces must be heated above the flow point of the alloy or a good bond will not be made. When the joint members vary greatly in thickness, as obtained when thin wall piping is brazed into a heavy flange, care must be taken to heat the flange until the inner surface which joins the pipe is at the correct temperature for the particular brazing alloy that is being used.

Probably one of the most difficult things that the workman has to acquire is the ability to judge when the joint is at the required temperature and at the same time not overheat the joint. Benches placed before windows are not good places to work because of the extreme variations in light conditions and strong drafts are also bad. The appearance of the flux is a guide, but if one is using a flux that is fluid at a temperature several hundred degrees below the proper brazing temperature the best indicator is to touch the alloy to the heated joint. In order to speed up the work there is a tendency to overheat the joint with consequent damage and workmen should be trained to judge the heat with reasonable accuracy.

APPLICATION OF SILVER BRAZING ALLOYS IN DIFFERENT INDUSTRIES

Electrical

Transformer leads and taps are brazed with silver alloys because of the low temperatures at which strong shock-resistant joints of high conductivity can be made.

Joints in bus bar installations of all kinds are being made with these alloys because of the high strength, corrosion resistance and elimination of voltage drop. Figure 6 shows a bus bar assembly being brazed. Ground connections and cable joints are also made.

In the manufacture of electric motors, end rings are bonded to rotor bars and many small parts in the manufacture of electrical equipment are brazed with silver alloys.

Lacing wires and shrouding are joined to turbine blades and in certain types of turbines the blades are silver alloy brazed to packing pieces.

Household Refrigerators and Air Conditioning

One of the largest new developments in the use of silver brazing alloys is in the manufacture of refrigeration units, both household and for industrial plants.

The low temperature at which they melt and the strong corrosion-resistant joints make them particularly desirable for joining the light metal sheets and tubing which are used in this industry. Joints are leakproof and when proper attention is given to design the cost is remarkably low.

The use of these alloys in air-conditioning systems is extending rapidly and has eliminated the old breakdowns that occurred with soft soldered joints and were often serious and caused damage from the escape of the refrigerant.

Piping

Standard pipe and fittings up to 10 inches or more in diameter are now being joined in increasing volume with these alloys, and tests on joints made in this manner show failure in the pipe or fitting when the work is done properly. Special fittings are being made with rings of silver brazing alloy fitted into grooves cut in the fittings, and this type of joint is being specified for marine and navy piping, and piping in buildings. Installations of silver-alloy brazed pipe and fittings in large steam plants have been in use for several years,

Fig. 7—Silver-Alloy Brazed Steam Piping

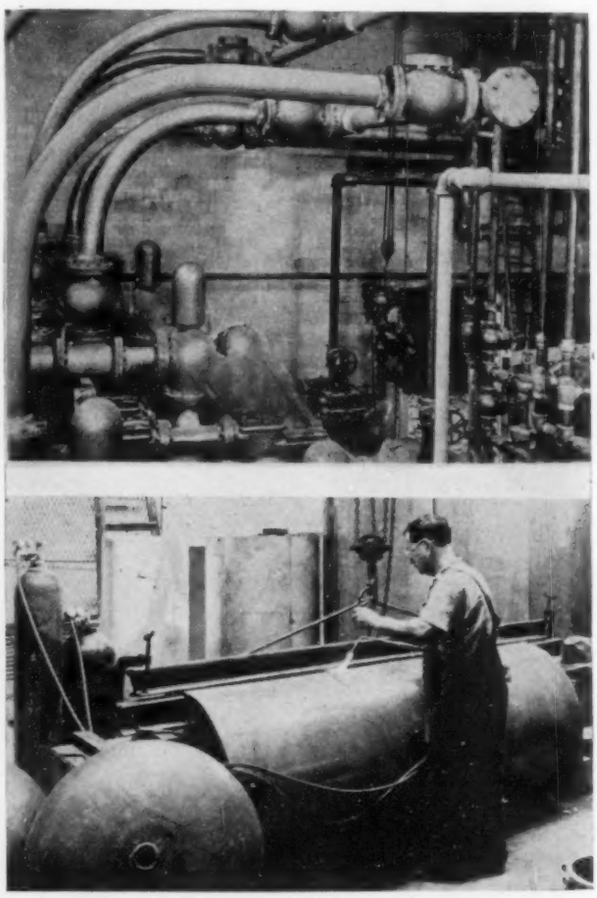


Fig. 8—Silver Brazing Copper Hot Water Tanks

and have given complete satisfaction. Figure 7 shows a typical illustration.

Joints made with silver brazing alloys on both similar and dissimilar metals for steam lines and boiler construction have been subjected to extreme tests entirely beyond anything to be expected in use and no signs of failure occurred in the brazed joint. One example is a steam boiler having 1237 copper tubes joined to mild steel headers 48 inches in diameter and $^3/_4$ inch thick. Brazing was done with a silver alloy melting at 1175° F. and under test this boiler was fired to 225 lb. pressure, steam and water blown out and cold water immediately pumped into the dry hot boiler. Repeated firing and cooling showed no failure in the brazed joints. Similar tests on assemblies of heavy-wall copper tubing and fittings brazed with an alloy melting at 1300° F. showed no failure when subjected to a steam pressure of 200 lb. per square inch and followed by the introduction of cold water for many repeated cycles.

Another unusual application was the construction of underground gas mains from heavy-wall copper tubing, using butt joints brazed with the silver-copper-phosphorus alloy which was previously mentioned. Ordinarily a bell and spigot type of joint would be used and it was recommended in this case. However, the results with the butt joints were so satisfactory that they were adopted.

Standard fittings with inserts of silver brazing alloys can be obtained for pipe sizes up to 10 inches in diameter or larger and flanges as large as 42 inches in diameter. The oxyacetylene torch has been most successful for heating joints of this type and there is every indication that this method of joining piping and fittings will show a large increase in the future.

Household Equipment

Silver brazing alloys are being used in the manufacture of many different articles used in the home, such as cooking utensils, hot water tanks, water heaters, flatirons, metal furniture and other applications where soft solders do not give the necessary strength and the temperature required for base-metal brazing alloys or welding rods would be too high. Figure 8 shows a copper hot-water tank being brazed with a silver brazing alloy which melts at 1300° F. and the heat is done with an oxyacetylene torch.

Other Uses

Silver brazing alloys are used in considerable quantities for the manufacture of chemical equipment, dairy and creamery equipment and in plants and equipment for the dye industry.

There are innumerable applications in the electrical, automotive and airplane industries where instruments, oil filters, oil coolers, gear shift levers, steering wheel spiders, contact joints, window frames, oil lines and radiator grilles are being brazed with these low-melting silver alloys.

There is a suitable silver brazing alloy available for making practically every type of joint on nearly all metals and alloys that melt at temperatures above 1250° F. As engineers become better acquainted with the strong neat joints that can be made quickly and economically with these alloys, at comparatively low temperatures, their use is being extended rapidly into all industrial fields and they provide an effective means of meeting many of the problems in the manufacture of modern equipment.

The author expresses his appreciation to his associates for their assistance and to Handy and Harman for permission to publish these data; also to the Air Reduction Company and to Walworth Company for photographs.

APPENDED LIST OF PAPERS

1. "Silver Solders," by Robert H. Leach, *A. S. T. M.*, **30**, April 2, 1930.
2. "Copper-Nickel (70-30) Alloy," by Mason S. Noyes, printed in *Journal of the American Society of Naval Engineers*, **48** (1), February 1936.
3. "The Navy's Soldered Fittings," by Mason S. Noyes, printed in *Journal of the American Society of Naval Engineers*, **47** (1), February 1935.
4. Instructions for making silver soldered joints and composition soldered fittings—Bureau of Engineering B-172-B-178. Also composition soldered union tube fittings—Bureau of Engineering, 3S-525, 3S-526, 3S-527 and B-117.
5. "Silver Soldering by Electricity," by Lieutenant P. H. Ryan, U. S. N., reprinted from *Journal of the American Society of Naval Engineers*, **48** (2), May 1936.
6. "Steam Turbine Materials for High Temperatures," Symposium on Effect of Temperature on the Properties of Metals—Joint meeting American Society for Mechanical Engineers and American Society for Testing Materials, June 23, 1931.
7. "Brazing Tubes in High Pressure Boilers with Silver Alloys," by A. W. Weir and H. M. Webber, AMERICAN WELDING SOCIETY Meeting, October 18, 1938.
8. "Incandescent Electric Carbon Silver Brazing," by Walter Reed and Leo Edelson, AMERICAN WELDING SOCIETY Meeting, Northern New York Section, February 17, 1938.
9. "Brazing with Silver Solders," by Robert H. Leach, AMERICAN WELDING SOCIETY, October 1-5, 1934.
10. "Metals Are Brazed in Controlled-Atmosphere Electric Furnaces," by H. M. Webber, reprinted from *Steel*, August 12 and 26, 1935.
11. "When and How Silver Solders Are Used," by Robert H. Leach, AMERICAN WELDING SOCIETY, Cleveland, October 1936.
12. "Silver Solders and Their Use," by Robert H. Leach, *Metals & Alloys*, November 1931.
13. "Silver Brazing Alloys in the Marine Field," by R. H. Leach and Leo Edelson, *Journal of the American Society of Naval Engineers*, **51** (1), February 1939.

WELDING METALLURGY

By O. H. HENRY and G. E. CLAUSSEN

A series of lectures prepared for presentation in a fundamental course of metallurgy and metallography at Polytechnic Institute of Brooklyn under the joint auspices of the Institute and the New York Section of the AMERICAN WELDING SOCIETY. To be published serially in The Welding Journal. Available in Pamphlet Form—47 pages Journal Size. Copiously Illustrated. $1.00 per copy. Special Prices quantity lots ten or more.

Part VI—The Weld Melt (Pure Iron)

Watch an operator making a fusion weld. Gaze along the gap between the two parts to be joined, Fig. 30, until your eye rests on the pool of molten metal which the operator maintains with his torch or arc. We shall call the pool of molten metal the "weld melt." When the weld melt solidifies, the two parts become welded together. What happens during the solidification of the weld melt?

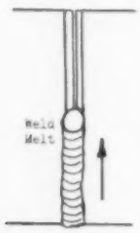


Fig. 30—A Weld in Progress, Showing the Weld Melt

Before we answer the solidification question, let us make certain that we know exactly what is happening to the metal at every instant after the torch or arc is first applied. For simplicity we shall weld pure iron. The instant the flame of the arc or torch is directed on the iron, its temperature rises; in other words, it gets hot. The temperature is hottest at the spot upon which the flame strikes. The heat absorbed from the flame spreads beyond the spot directly under the flame into the adjacent metal, whose temperature rises, the rise in temperature being greatest at the spot upon which the flame impinges and decreasing rapidly as the distance from the flame is increased.

The sequence of events is depicted on the thermometer, Fig. 31. Starting at the bottom we find that the temperature rises steadily at first. At about 500° C. any distorted grains resulting from cold rolling or other cold work recrystallize. The hardness due to cold work is lost when the grains recrystallize and revert to the soft condition.

At 900° C. there is a transition from ferrite to austenite. The ferrite is a body centered cubic crystal, Fig. 32, whereas the austenite is face centered. The transition, like all transitions in pure metals, starts and completes itself at 900° C. Further, like all transition heating, heat is absorbed in changing the crystals around. As a result there is a halt in the rate of heating. The new austenite crystals grow as the temperature is raised, until at 1400° C. there is another transition. The face centered cubic crystals change back to body centered cubic. Further rise in temperature brings these new crystals to the melting point of iron = 1530° C.

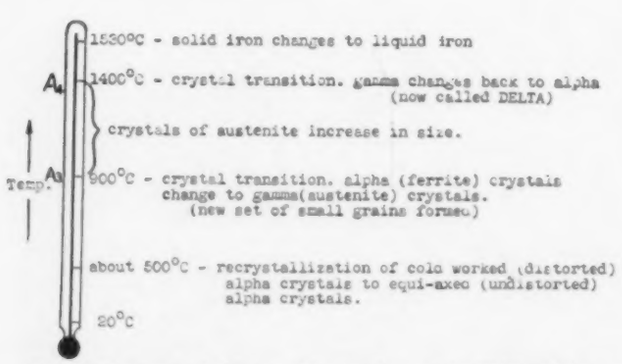

1530°C - solid iron changes to liquid iron
A4
1400°C - crystal transition. gamma changes back to alpha (now called DELTA)
crystals of austenite increase in size.
Temp.
A3
900°C - crystal transition. alpha (ferrite) crystals change to gamma(austenite) crystals. (new set of small grains formed)
about 500°C - recrystallization of cold worked (distorted) alpha crystals to equi-axed (undistorted) alpha crystals.
20°C

Fig. 31—Sequence of Events on Heating Iron to the Melting Point

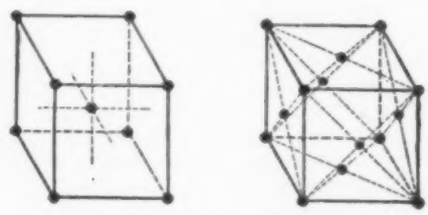


Fig. 32—Crystalline Forms of Iron
(*a*) and (*b*) body-centered cubic packing; alpha and delta iron
(*c*) and (*d*) face-centered cubic packing; gamma iron

The first atom to melt does so by leaving the crystal lattice. Others soon follow to form the weld melt in which the atoms move freely about, Fig. 33. Melting, like a transition, requires heat for its completion. Hence, if the temperature of the iron under the flame is rising steadily before melting starts, it will stop rising and will remain at 1530° C. during melting. As soon as the metal is molten its temperature rises again under the flame while boundary *ABC*, Fig. 34, representing 1530° C. and the line along which atoms change from solid to liquid, extends deeper into the iron. The flame (arc) is exceedingly concentrated and at a high temperature the molten metal in the vicinity will be overheated and may reach the boiling point. Unlike the boiling of a pot of water on a stove, which starts to boil at the bottom, the weld metal reaches the boiling temperature at the surface, and therefore there is no bubbling. Any bubbling of the weld metal that may be observed is due to other causes than boiling, as we shall see later.

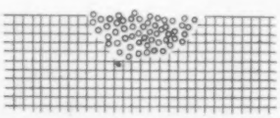


Fig. 33—The Weld Melt Contrasted with the Crystal Lattice
Extremely high magnification showing the crystal lattice with imaginary atoms at each intersection, with liquid in which the atoms are free to move about

We are now ready to study solidification. The liquid initially extended over the cross section *ABC*, Fig. 35. Solidification proceeds after the flame has passed on, by atoms of the melt attaching themselves to the crystals of base metal. Columnar crystals are formed. As the solidified iron cools, it passes through the transition at 1400° C. and 900° C. At each transition there is a change (refinement) of grain size and an evolution of heat, just as at the freezing temperature.

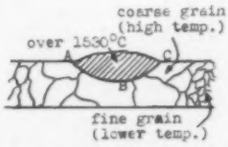


Fig. 34—Puddle of Molten Metal on Iron Plate
There is a sharp boundary, ABC, representing a temperature of 1530° C. between solid and melt

THE WELD MELT (STEEL)

Strange to say, if the weld melt is steel instead of pure iron, there are important differences in the sequence of events from those shown on the pure iron thermometer. Of course, the way in which the atoms of the melt attach themselves to the crystal lattice during freezing is the same for steel as for pure iron. However, steel contains carbon and other elements. On that account, melting, freezing and the transitions take place over a range of temperatures, instead of at a single temperature. These ranges of temperatures have been determined by the metallurgist for all plain carbon steels. He plots them on an equilibrium diagram, which will now be discussed.

The equilibrium diagram is the result of combining schematic thermometers for every steel, similar to the thermometer for pure iron, into a single diagram. If close attention is given to the twelve accompanying diagrams, Fig. 36, there will be no difficulty in mastering the subject.

Diagram 1.—The schematic thermometer called the temperature axis of the equilibrium diagram.

Diagram 2.—Steel contains iron and carbon. To represent mixtures of two materials, such as iron and carbon, we draw a horizontal line and call one end material A, the other end material B. If the line is 10 inches long, then a point on the line 5 inches from either end is said to be a mixture of 50% A and 50% B. Similarly, a point $2^1/_2$ inches from A has the composition 75% A, 25% B

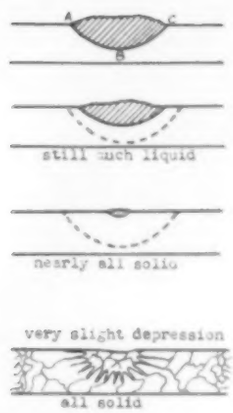


Fig. 35—Four Stages in Solidification
Shaded area is melt; dotted line is boundary of initial melt

Diagram 3.—The temperature and composition axes (lines) have been combined into a single diagram. Any

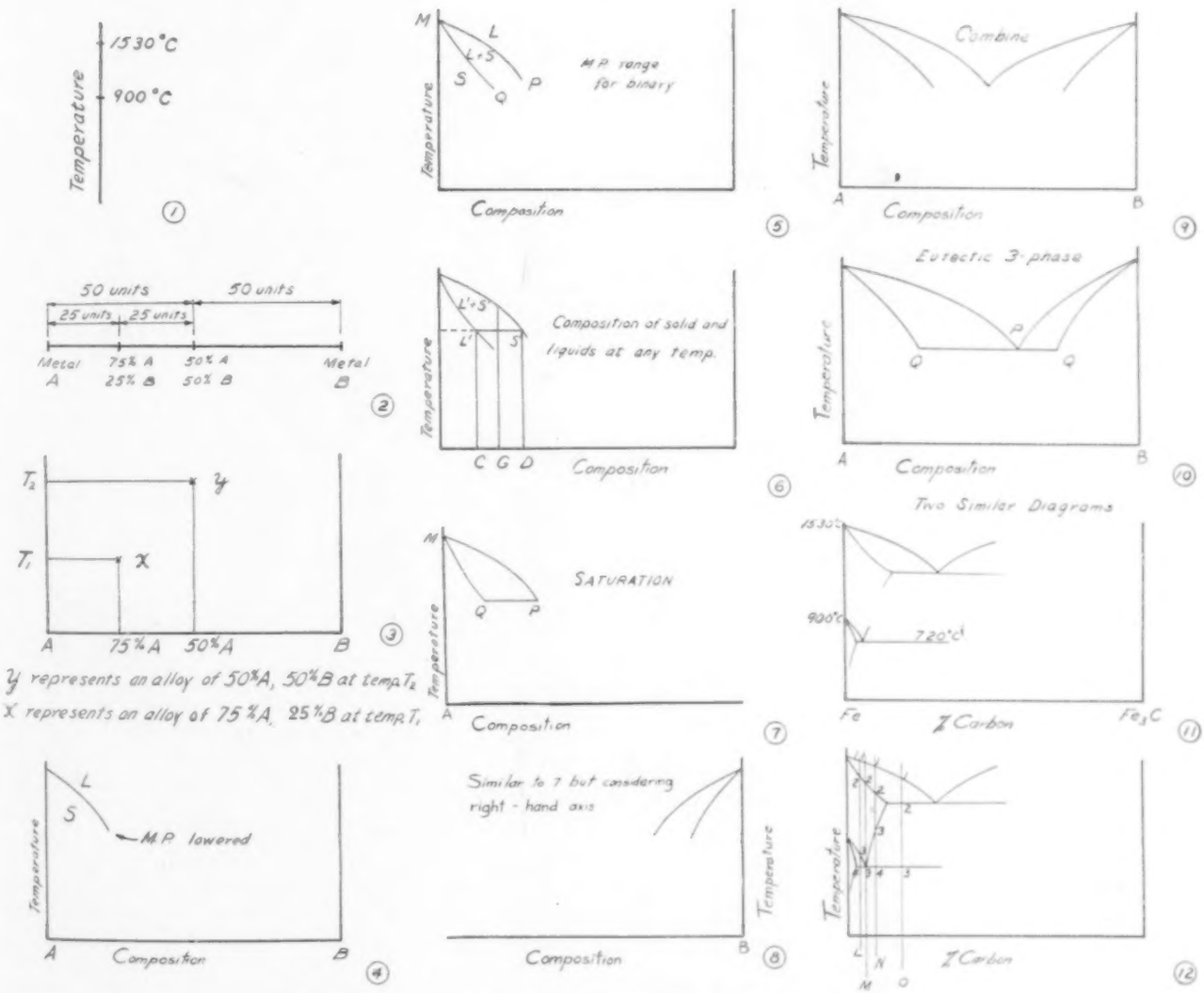


Fig. 36—Twelve Diagrams Showing How an Equilibrium Diagram Is Formed

point in the diagram represents an alloy of the composition shown by the vertical dropped on the composition axis, at a temperature shown by the horizontal intersecting the temperature axis.

Diagram 4.—A composition-temperature diagram. The curved line shows the temperature at which some of the alloys start to freeze. As *B* is added to *A*, the freezing point is lowered. Sometimes another material raises the freezing temperature. If the two materials do not dissolve in each other, the melting or transition temperatures of each are not changed by the presence of the other.

Diagram 5.—A mixture of two elements solidifies at a single temperature only if the mixture is a compound or eutectic, which is unusual. Ordinarily a mixture of two metals solidifies over a range of temperatures. That is to say, crystals form in the melt along *MP*. The alloy is not completely solid until the temperature has fallen to *MQ*. At temperatures between *MP* and *MQ* the alloy consists of a mush of liquid and crystals.

Line *MP* is called the liquidus.
Line *MQ* is called the solidus.

Diagram 6.—Suppose alloy *G* is at temperature *T*. It consists of a mush of liquid and crystals. If the cooling or heating has been extremely slow, the composition of the liquid is *D*, the composition of the crystals is *C*. As a consequence, the Lever Law:

$$100 \times \frac{GD}{CD} = \text{percentage of total mass in the crystalline condition.}$$

$$100 \times \frac{CG}{CD} = \text{percentage of total mass existing as a liquid.}$$

Diagram 7.—Saturation. Diagram 4 shows that *A* and *B* are soluble in the liquid state. Diagram 5 expresses the fact that *A* and *B* are soluble in the solid state. Line *MQ* shows the saturated solid solutions. They are saturated because if *B* is added to an alloy on line *MQ*, some liquid rich in *B* "precipitates" from the crystalline solid.

Below *PQ* liquid can no longer exist.

Diagram 8.—A similar behavior may be displayed when *A* is added to *B*.

Diagram 9.—Shows the intersection of the two liquid lines at the temperature and composition known as the *Eutectic*.

Diagram 10.—Liquid does not exist below the temperature of the eutectic horizontal *QPQ'*. Along *QPQ'*, melt *P* solidifies to form an eutectic mixture of the saturated solid solutions *Q* and *Q'*.

Diagram 11.—In the vicinity of a transition solid solutions of two metals behave as liquid solutions behave in the vicinity of the melting temperature.

Diagram 12.—A single line added to diagram 11 completes the equilibrium diagram for steel.

THE IRON, IRON CARBIDE EQUILIBRIUM DIAGRAM

The customary form of the iron-iron carbide equilibrium diagram that is used for reference is shown in Fig. 36. As usual, vertical distances represent temperature, the Fahrenheit scale being on the left, Centigrade on the right. Horizontal distances represent composition in weight per cent carbon. Simply to magnify the space occupied by the lower carbon contents, the composition is plotted logarithmically, there being no hidden significance. We recognize on the left-hand vertical axis, which represents iron free from carbon 0% C, the familiar temperatures:

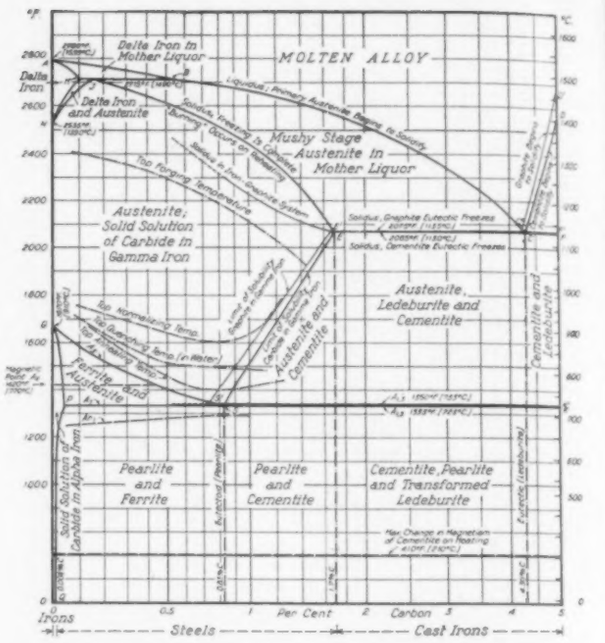


Fig. 37—Iron, Iron Carbide Equilibrium Diagram (Metal Progress)
Carbon content is plotted logarithmically for convenience in magnifying the lower carbon range

A—Melting point of iron.
N—A_4 transition (delta iron (body centered cubic) changes to gamma iron (face centered cubic) on cooling or vice versa on heating).
G—A_3 transition (gamma iron (face centered cubic) changes to alpha iron (body centered cubic) on cooling or vice versa on heating).

The "magnetic point" at 770° C. represents the temperature at which alpha iron becomes magnetic on cooling or loses its magnetism on heating.

Addition of carbon to iron lowers the melting temperatures and causes melting to occur over a range of temperatures. The liquidus (temperature at which crystals appear on cooling) is *ABCD*. The crystals which appear in the melt when the temperature reaches *AB* are delta iron. Their compositions are represented by *AH*, a part of the solidus *AHJEF*. Unlike ferrite and austenite, delta iron is the term used to designate both iron free from carbon and solid solutions of iron and carbon having the body centered cubic form between 1390 and 1535° C.

Similarly the austenite crystals which appear in the melt when the temperature reaches *BC* on cooling are of the compositions shown by line *JE*. For example, at 2200° F. we cannot have a crystal containing 2% C; if there is melt present the only possible austenite crystal contains 1.5% C. The austenite separating along *BC* is called primary austenite to distinguish it from the austenite that separates from delta iron along *HN* during cooling, which is called secondary austenite.

HJB—Peritectic line.
H—Delta iron of peritectic composition, 0.08% C.
J—Gamma iron of peritectic composition, 0.18% C.
B—Peritectic liquid, 0.55% C.

The crystals which appear in melts containing over 4.30% C when the temperature reaches *CD* on cooling are cementite, Fe_3C. The corresponding solidus is not shown, for the reason that its position is not too well known.

ECF—Part of the eutectic line.
E—Eutectic austenite.

C—The eutectic, also called Ledeburite.

The right-hand end of the eutectic line extends to 6.67% C, corresponding to the composition of cementite, Fe_3C. Along *ECF*, the three materials, *E*, *C* and cementite are in equilibrium. If heat is applied, *E* and cementite react to form a liquid containing 4.30% C at constant temperature, 1130° C. If heat is removed, the eutectic liquid, *C*, discharges austenite *E* and cementite in finely divided, eutectic form. *C* is called the "cementite eutectic" to distinguish it from a liquid *C'* of slightly lower carbon content, which freezes as a eutectic of austenite and graphite. Except in the welding of cast iron, graphite is of no importance for welding. Liquid is not found below the solidus *AHJEF*.

Aside from the unimportant lines *NH* and *NJ*, there are only five lines in the equilibrium diagram below the solidus, and only two other joints *P* and *S*, which we have not discussed in detail Lines *GS* and *SE* are analogous to curves *AC* and *CD*; "molten alloy" (liquid solution) is analogous to "austenite" (solid solution). When solid solution called austenite reaches *GS* (A_3) on cooling, crystals of ferrite appear. Their composition is shown by line *GP*. Ferrite alone, without cementite or austenite can exist only in area *GPQO*. For example, at 1400° F. we cannot have a ferrite crystal containing 0.20% C. We can have ferrite crystals containing up to a maximum of 0.03% C at 1400° F. When austenite reaches *SE* (A_{cm}) on cooling, crystals of cementite appear.

PSK—Part of the eutectoid line.

P—eutectoid ferrite, containing 0.035% C.

S—the eutectoid, containing 0.83% C.

The right end of the eutectoid line extends to 6.67% C, corresponding to the composition of cementite, Fe_3C. Along the line *PSK* the materials P, S and cementite are in equilibrium. If heat is applied, P and cementite react to form austenite of composition S, 0.83% C, at 723° C. On the other hand, if heat is removed S decomposes into ferrite (P) and cementite The crystals of ferrite and cementite have the appearance of plates, a thin plate of cementite separating every pair of ferrite plates. The structure consisting of alternate plates of ferrite and cementite is called pearlite. The dashed line labeled A_{r1}, signifies that the evolution of heat at the eutectoid during cooling at rates commonly prevailing in the laboratory occurs 20 to 40° C. below the equilibrium temperature measured during infinitely slow cooling.

At first, the convenience of the equilibrium diagram will not be realized. It will be argued that alloys practically never attain equilibrium conditions in practice, particularly in welding, where fast rates of cooling are the rule. It is true that the equilibrium diagram for practical purposes applies only to rather slow cooling rates, such as during cooling a $^1/_2$-inch plate in still air. Nevertheless, the diagram always is essentially correct for the weld melt, no matter what the rate of cooling, for the molten metal always crystallizes. The transition at 720 to 900° C., however, is suppressed by rapid cooling. We study the effect of rapid cooling on the transition later.

To facilitate comprehension of the iron-iron carbide equilibrium diagram, the eight "thermometers" in Fig. 38 depict the sequence of events in heating and cooling 4 typical iron-carbon alloys. Note that the numbers on the thermometers are also on the equilibrium diagram 12, Fig. 36. For simplicity the transition at 1400° C. in iron has been neglected.

Questions

1. Draw a diagram recording the events which occur within a piece of steel as the welding torch or arc brings it to the melting point.
2. Point out the "critical ranges" in the iron-iron carbide equilibrium diagram.
3. With the aid of the equilibrium diagram draw a "thermometer" for steels containing 0.10 and 0.40 C. What are the critical ranges for these steels and at what temperatures do they commence to melt and freeze?
4. Point to the line or curve on the equilibrium diagram below which austenite does not exist under equilibrium conditions.

Part VII—Difficulties

Mushy Stage and Hot Cracks

While the equilibrium diagram is being discussed, two occurrences in the weld metal will be explained. First, in any commercial weld melt there are alloying elements and impurities (manganese, phosphorus, molybdenum, etc.) that cause freezing to occur over a range of temperatures, 30 or 40° C. for mild steel. As the weld melt cools and reaches the liquidus temperature, the first crystal to form contains a greater percentage of iron and therefore a lower percentage of carbon than the weld melt, Fig. 39. After the temperature has fallen 10° or so, the weld melt is a mixture of liquid fairly high in carbon content and of crystals fairly low in carbon content. The melt is in the *mushy stage*. Use is made of the mushy stage in plumber's wiping solder, in which a tin-rich liquid contains nearly pure crystals of lead.

Although the mass may give the impression of solidity it has no tensile strength. Not until every drop of liquid has frozen will the weld metal possess strength and ductility. For this reason, if the parts upon which the weld is being made are vibrating or are under stress due to the heat of welding, a crack may form in the weld metal that has nearly frozen but that still retains a minute proportion of liquid. The crack opens out without visible deformation of the metal, and will have a blued or scaled appearance in steel after it has cooled to room temperature.

Cracks formed in the mushy stage are known as *hot cracks*. The liquid responsible for the cracks is in the spaces between the growing crystals; hence the fracture is intercrystalline. There is one impurity in steel that has a particularly bad reputation for hot cracks, namely sulphur. Sulphur reacts with iron to form iron sulphide, *FeS*. A few hundredths of one per cent of iron sulphide in steel increases the range of temperatures during which freezing occurs from 30 or 40° to 400 or 500° C. The last trace of sulphur-rich liquid between the crystals does not freeze until about 1000° C. Viewed from another angle, if a steel containing iron sulphide is heated above about 1000° C., the steel commences to melt and hot cracks readily form; the steel is called *red short*. There may be other causes of hot cracks and red shortness, such as oxygen, but sulphur is the most important.

Fortunately, there is no need to reduce the sulphur

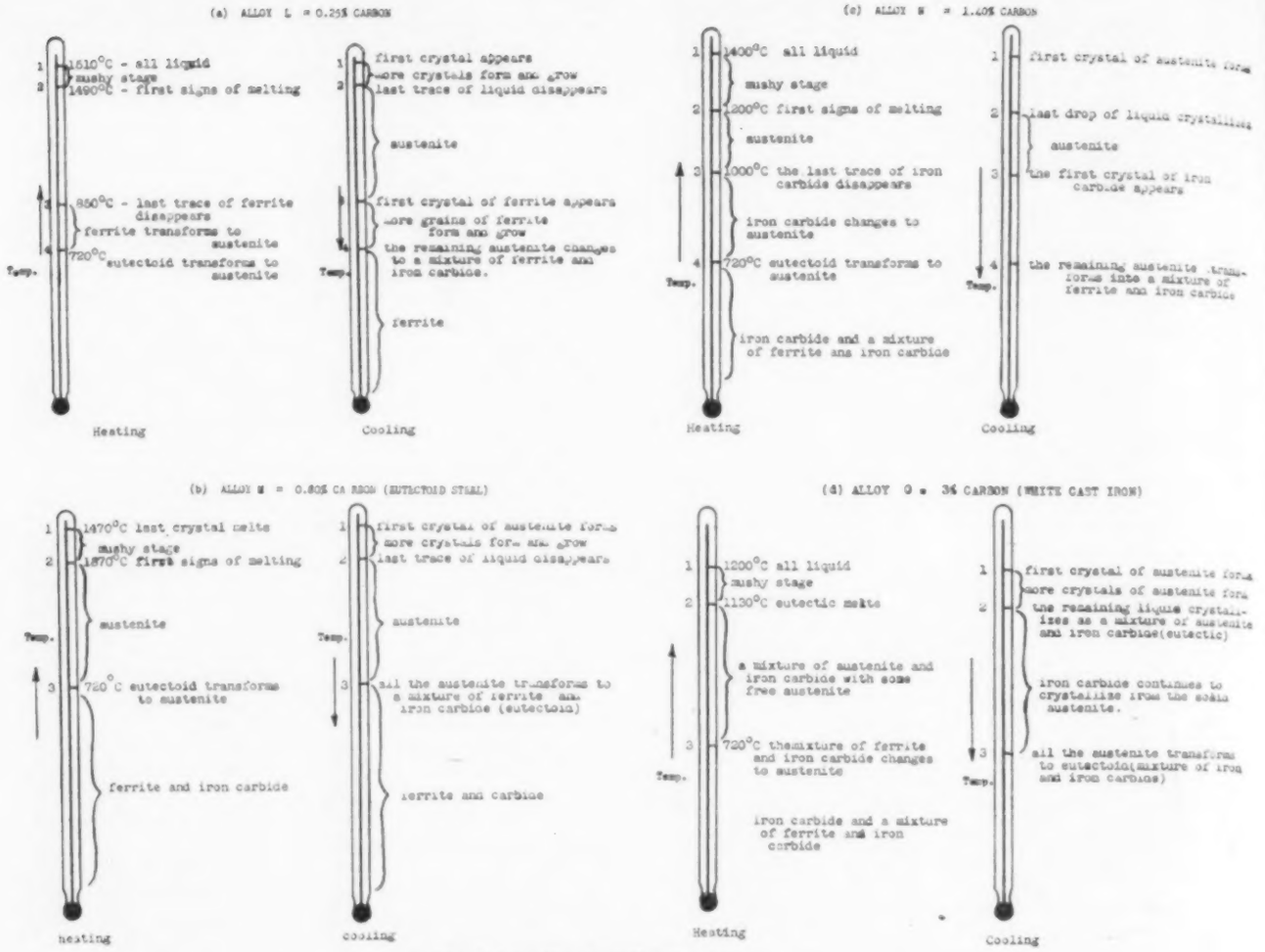

(a) ALLOY L = 0.25% CARBON
1610°C - all liquid
mushy stage
1490°C - first signs of melting
850°C - last trace of ferrite disappears
ferrite transforms to austenite
720°C eutectoid transforms to austenite
Temp.
Heating
first crystal appears
more crystals form and grow
last trace of liquid disappears
austenite
first crystal of ferrite appears
more grains of ferrite form and grow
the remaining austenite changes to a mixture of ferrite and iron carbide.
ferrite
Cooling
(c) ALLOY N = 1.40% CARBON
1400°C all liquid
mushy stage
1200°C first signs of melting
austenite
1000°C the last trace of iron carbide disappears
iron carbide changes to austenite
720°C eutectoid transforms to austenite
iron carbide and a mixture of ferrite and iron carbide
Heating
first crystal of austenite forms
last drop of liquid crystallizes
austenite
the first crystal of iron carbide appears
the remaining austenite transforms into a mixture of ferrite and iron carbide
Cooling
(b) ALLOY M = 0.80% CARBON (EUTECTOID STEEL)
1470°C last crystal melts
mushy stage
1370°C first signs of melting
austenite
760°C eutectoid transforms to austenite
ferrite and iron carbide
heating
first crystal of austenite forms
more crystals form and grow
last trace of liquid disappears
austenite
all the austenite transforms to a mixture of ferrite and iron carbide (eutectoid)
ferrite and carbide
cooling
(d) ALLOY O = 3% CARBON (WHITE CAST IRON)
1200°C all liquid
mushy stage
1130°C eutectic melts
a mixture of austenite and iron carbide with some free austenite
720°C themixture of ferrite and iron carbide changes to austenite
iron carbide and a mixture of ferrite and iron carbide
Heating
first crystal of austenite forms
more crystals of austenite form
the remaining liquid crystallizes as a mixture of austenite and iron carbide(eutectic)
iron carbide continues to crystallize from the solid austenite.
all the austenite transforms to eutectoid(mixture of iron and iron carbide)
Cooling

Fig. 38 (*a*)—Alloy L—0.25% Carbon
(*b*)—Alloy M—0.80% Carbon (Eutectoid Steel)
(*c*)—Alloy N—1.40% Carbon
(*d*)—Alloy O—3% Carbon (White Cast Iron)

content of steels below 0.05% ordinarily, because if manganese is present to the extent of 0.30%, manganese sulphide replaces iron sulphide. Manganese sulphide, unlike iron sulphide, does not dissolve in liquid steel. Therefore, manganese sulphide does not increase the freezing range; in fact, the manganese sulphide solidifies as globules in the liquid steel. In the globular form, sulphur is harmless, but in the form of iron sulphide at the crystal boundaries, sulphur leads to hot cracks under tensile stress or hammer blows at a bright red heat.

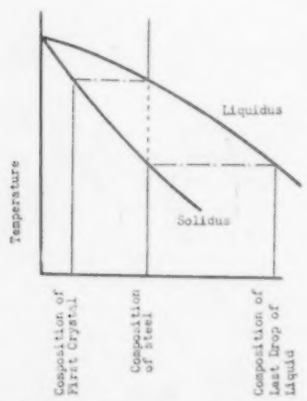


Fig. 39—When the Steel Is Between Liquidus and Solidus, It Is in the Mushy Stage

It is a curious fact that in a melt of steel containing manganese and sulphur, some of the sulphur is in the form of manganese sulphide, some as iron sulphide. As the manganese content is increased, the amount of iron sulphide that can exist rapidly diminishes, for manganese has a greater affinity for sulphur than iron. Furthermore, the proportion of manganese sulphide in molten and solid steel increases as the temperature is lowered. Overheating the weld puddle is disadvantageous in that it increases the proportion of iron sulphide, as well as for other reasons (crystal size, loss of elements by oxidation). For instance, overheating may cause the manganese to oxidize and join the slag; as a result, the weld melt will have insufficient manganese to prevent the formation of considerable amounts of iron sulphide. The manganese in welding may be alloyed with the filler rod or may be added to the electrode coating.

Burning

In any discussion of the heating of steel to 1200° C. and above (white heat), the term "burning" is bound to be mentioned. By burning one of three phenomena may be meant.

1. Burning in the sense of oxygen cutting.
2. The penetration of oxides along the grain boundaries of steel, rendering it brittle and fit only for remelting.
3. The partial melting of the steel.

Definition 1 is obvious. The intergranular oxidation

in the second definition occurs when the steel is heated in an oxidizing furnace atmosphere above about 1200° C. Ordinarily the oxide does not penetrate rapidly and it may require a half hour or more for the formation of a deep layer of grains surrounded by oxide. Under the cogging rolls or forging hammer at any temperature, steel oxidized in this way will break up. Burning in the sense of definition 2 never occurs in any type of fusion welding because there is *flux* over the metal and an atmosphere that is not oxidizing while the metal is at white heat.

The partial melting of steel occurs when it is heated above the *solidus* temperature. If the steel is hot short, the sulphide commences to melt in the grain boundaries at 1000° C. or above. No matter what the composition of the steel, it commences to melt in the grain boundaries, with isolated patches of liquid metal forming within the grains. Should the steel be forged while liquid is in the grain boundaries, the steel will break up. We would expect this behavior of any alloy in the mushy stage. If the steel is cooled to a temperature at which

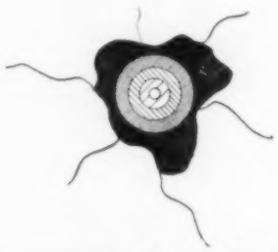


Fig. 40—Coring. Diagrammatic Sketch in Which Depth of Shading Increases as the Percentage of Carbon and Alloying Elements Increases. Frequently Observed in Cast, Alloy Steel, Coring Is Rarely Seen in Mild Steel Weld Metal. Coring Is Removed by Full Annealing. Instead of the Circles Shown for Simplicity Above, Coring Generally Has a Dendritic Appearance, and Is Revealed by Etching

there is no longer any liquid in the grain boundaries, it regains its ductility.

The behavior of steel when it is burnt in the sense of definition 3 is exactly the same as the behavior in the preceding section on the mushy stage. Every fusion weld passes through the mushy stage and in that sense has been in the burnt condition, albeit for an exceedingly short period and with no ill effects. It is important to understand that no fusion weld is burnt in the sense of definition 2, which is the more common sense in which steel men use the term.

Segregation and Pipe

The equilibrium diagram shows that the first crystals to solidify from the molten steel are rich in iron and low in carbon and alloying elements. As freezing progresses, the crystals that separate and the material that is added

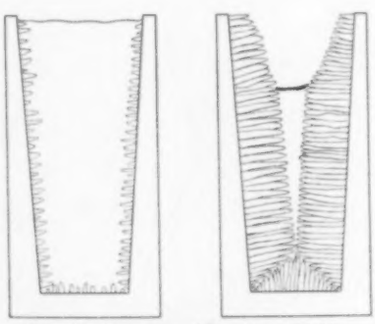


Fig. 41—Freezing of Steel in a Mold
Left—Freezing Begun
Right—Freezing Nearly Complete

to the existing crystals, are richer in carbon and alloying elements, Fig. 40. Unless cooling is unusually slow there will be insufficient time for equalization of composition between the core of a crystal and the last layers that freeze. The resulting difference in composition between center and outer portions of a crystal is called *coring*. Coring is often evident, for example, in metal deposited by 18–8 electrodes. Coring may be an advantage or disadvantage, depending on circumstances.

Entirely different from coring is *segregation*, which seldom is observed in weld metal. In castings and ingots, however, segregation is a major difficulty. The first material to freeze in an ingot mold is rich in iron and crystallizes at the coolest surfaces, the mold walls. The remaining liquid at the center is richer in carbon and particularly in the impurity sulphur, than the initial melt. By the time most of the ingot has solidified, the liquid, which still occupies the upper center portion of the mold, usually is rather high in impurities. For example, the first crystals to form may contain 0.02 S, whereas the last liquid to freeze may contain 0.08 S.

The difference in composition between the center and outer portions of the solidified ingot is called segregation. In contrast with coring which may be equalized by annealing, segregation is permanent. Ingot molds, Fig. 41, must be designed so that the regions of worst segregation will be removed when the ingot is cropped before rolling. Even so, it is unusual for wrought products to be free from segregation, which is estimated by sulphur printing (soak ordinary sensitized photographic silver bromide paper in a 2% solution of sulphuric acid in water. Apply emulsion side of paper to smooth ground, clean sample for a minute or two. Rinse paper, fix in hypo, wash thoroughly. The brown pattern formed on the paper indicates the relative distribution of sulphides. The darker and heavier the marks, the more sulphur is indicated to be present).

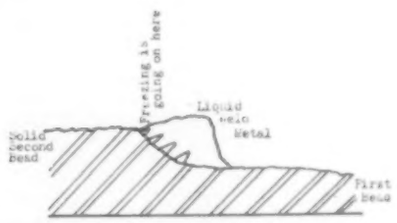


Fig. 42—Solidification of a Second Bead of Weld Metal on the First Bead

Segregation is not observed in fusion welds because the bath of weld metal is being stirred and because the crystals advance into the weld melt from one surface only, Fig. 42. New metal of constant composition is constantly being added to or puddled into, the weld at the other end.

Reverting to the diagrams of solidification of steel in an ingot mold, we observe that the level of the liquid falls as freezing progresses, because the crystals occupy less space (are denser) than the liquid. When the last drop of liquid has solidified, there remains a more or less deep cavity, called a *pipe*, in the upper center portion of the ingot, unless special precautions are taken to prevent its formation. Pipe cavities can be distinguished from blowholes by the dendritic appearance of the pipe. The liquid has drawn away from the growing crystal, exposing its dendritic structure. Upon rare occasions wrought steel containing rolled-out pipe cavities will be presented for welding. Since the welding heat tends to open out the oxidized pipe cavity, the steel should not be welded.

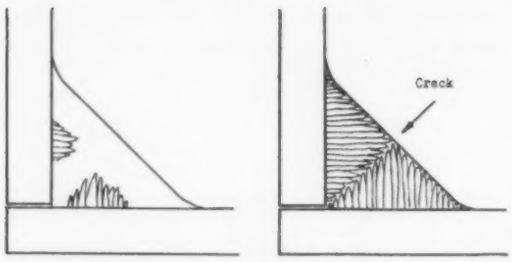


Fig. 43—Possible Source of a Crack in a Single-Bead Fillet Weld. Solidification Starts at Both Walls Instead of at the Root of the Weld, in This Instance

In fillet welding, conditions may be such that solidification starts at the root or at both sides. If solidification starts at both sides, Fig. 43, there is a tendency to form a pipe cavity or crack through the throat of the weld. The root angle will be less sharp if successive layers are deposited, but the initial crack may tend to propagate through them.

Blow-Holes

Blow-holes are smooth, bright cavities of rounded contour sometimes observed in fusion weld metal. Blow-holes represent bubbles of gas in the liquid weld metal that have not risen to the surface owing to lack of time and to the viscosity of the weld melt. Blow-holes arise from two effects:

1. Gases are less soluble in liquid steel at low temperatures than at high temperatures. Hydrogen and carbon monoxide are the two gases with which liquid steel may be saturated in fusion welding. Both gases may be

Fig. 44—Gas Bubbles May Be Liberated During the Crystallization of the Weld Melt, and May Be Entrapped in the Growing Crystals. Porosity Is the Result

derived from the welding gas or coating. During cooling from a high temperature after saturation, the gas comes out of solution in the form of bubbles. If the bubbles are trapped in the growing crystals, instead of rising to the surface of the melt, blow-holes are formed. To avoid blow-holes avoid overheating but arrange that the weld melt solidifies continuously, not intermittently in large steps.

2. Mild steel weld metal contains carbon and oxygen in solution. When crystallization commences, the first crystals to freeze are low in carbon, according to the equilibrium diagram. The remaining liquid is enriched in carbon and a reaction occurs between carbon and dissolved oxygen to form carbon monoxide. The bubbles may create a foam, indicative of improper welding conditions. The corrective is manganese and particularly silicon, which, when added to the weld melt through the filler rod, remove the dissolved oxygen from the steel as liquid oxide of manganese or solid oxide of silicon (silica).

A similar reaction occurs in the welding of steel containing unusually high sulphur, the gas evolved being sulphur dioxide (SO_2). A segregated steel in which the sulphur content is high only in the center of the plate may also produce porous welds through the formation of SO_2.

The distribution of temperature in the weld melt should enter any discussion of blow-holes. Gas is absorbed in the region of highest temperature under the flame, Fig. 44. The gas is evolved particularly among the growing crystals, for a gas is much less soluble in crystals than in liquid metal at the melting point. Agitation of the melt tends to equalize the temperature of the weld melt and favors absorption of gases. The surface of the weld melt always is at a higher temperature than the bottom of the melt. The weld melt, therefore, tends to freeze from the bottom up, which is favorable to the evolution of gas in flat position welding. If the tempera-

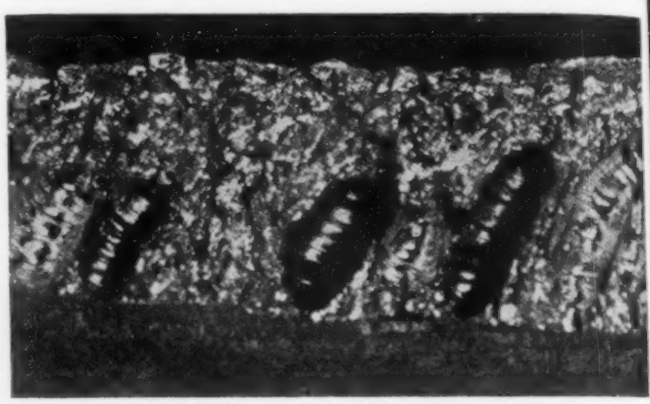


Fig. 45—Worm Holes (Blomberg)

ture range over which solidification occurs is large, the gas bubbles evolved have more opportunity to rise to the surface than if the range is small. The progressive evolution of gas during freezing results in "worm holes," elongated blow-holes trapped in the viscous melt among the growing crystals, Fig. 45.

Slag Inclusions

Nearly always the weld melt is covered by a thin layer of slag, which is formed from the flux in gas welding or from the coating in arc welding. The slag covers the melt except directly under the flame, Fig. 46. Under the flame the slag is churned into the weld melt, which is benefited thereby. Farther from the flame the slag

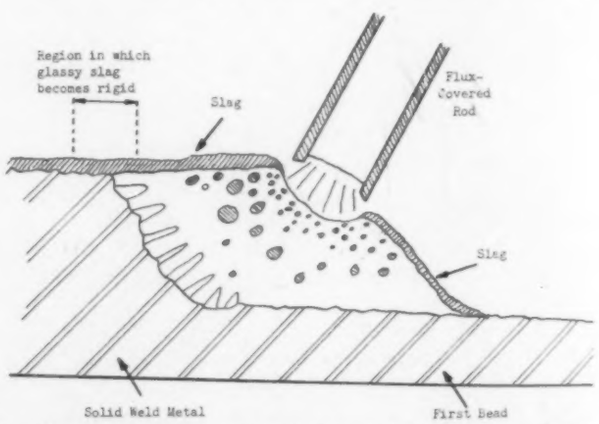


Fig. 46—Flux Is Churned Into Weld Melt, Quickly Coalesces and Rises to Join the Fluid Layer of Slag. Note Slag Clearing the Way for the Weld Metal

particles coalesce. The larger the particle, the more rapidly it rises to the surface of the shallow weld melt where it joins the rest of the slag. The slag blanket cleans the surface of the steel in advance of the weld melt and protects the molten metal from the atmosphere.

If globules of slag are trapped among the growing crystals at the left end of the weld melt in Fig. 46, *slag inclusions*, as they are called, will appear in the weld. In overhead welding the operator can allow only an exceedingly short time for the melt to freeze, otherwise there is dripping. Consequently, overhead welds tend to have more slag inclusions than flat position welds. In addition to slag from the flux or coating, some slag may form through reaction of silicon and other deoxidizers in the filler rod with the oxygen in the melt. To hasten the rise of slag to the surface of the melt, it might be thought sufficient to lessen the resistance to the rise of the globules. The depth of the melt has little effect on the trapping of slag inclusions because the deeper melt solidifies more slowly, which allows time for the inclusions to rise. However, the hotter the melt, the more fluid it

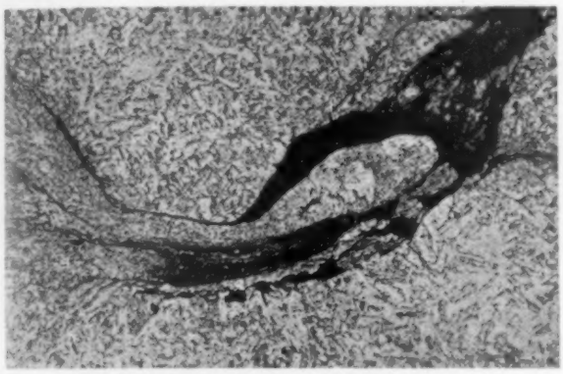


Fig. 47—Films of Oxide in a Weld (Hoffmann)

is, and the less resistance is offered to the rise of the inclusions. A little reflection will show that the advantage of raising the temperature of the bath is outweighed by disadvantages. As the temperature is raised the slag on the surface becomes more fluid (less viscous), and does not cover the metal to the proper extent. Then, too, at elevated temperatures the weld melt dissolves slag to a greater extent. Intentional over-heating therefore is not good policy.

Summarizing, the following factors chiefly affect the trapping of slag inclusions.

1. Viscosity of Melt.—The more viscous the melt, the slower the inclusions coalesce and rise to the surface. The viscosity of the weld melt rapidly increases as the melt cools.

2. Temperature.—The higher the temperature, the greater is the extent to which slag dissolves in the weld metal, which is a disadvantage.

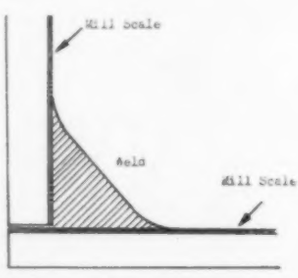


Fig. 48—Penetration Sometimes Signifies Fusing Completely Through the Layer of Mill Scale. In This Respect the Above Weld Is Completely Defective

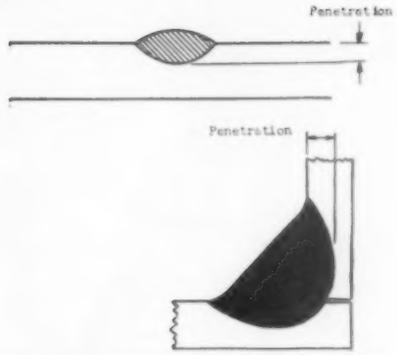


Fig. 49—Penetration Sometimes Is Called the Depth to Which the Fused Zone Extends Below the Surface, in Other Words, Depth of Fusion
Above—Penetration of a weld bead into the surface
Below—Penetration in a fillet weld

3. Rate of Cooling.—The faster the rate of freezing, the greater is the likelihood of trapping slag inclusions.

4. Stirring.—The greater the agitation of the bath, the greater the likelihood of trapping slag.

Besides the globular slag inclusions, which have comparatively little effect on the mechanical properties of a weld if there are not too many large ones, elongated, film-shaped slag inclusions may occur under exceptionally poor conditions. The film-shaped inclusions are not permissible in quality welds. They arise in two ways. (1) If the filler rod is added drop by drop and there is inadequate flux, a film of oxide forms around each drop in an oxidizing atmosphere. Unless the melt is stirred to work the film to the surface, it will remain in the weld, Fig. 47. (2) If a new bead is started at the end of a previous bead (for example upon changing electrodes) without chipping, the scale on the first bead remains in the weld unless precautions are taken to work it to the surface. The flowing of new metal over a scale-covered bead creates a condition known in the foundry as a *shut*. When weld metal spatters on the scarves ahead and the operator hastily deposits metal over the oxide-covered globules, the films coating the globules may remain in the weld.

Fig. 50—The Weld Metal (Shaded) Has Failed to Flow to the Full Depth of the Root; Sometimes Called Inadequate Penetration. Note Failure of Weld Metal to Wash Up on the Scarf, Which Often Is Observed When the Flux Does Not Lower the Surface Tension Sufficiently, or When the Operator Is Hasty

Penetration

Penetration is an important but complex term. At least three meanings are attached to it.

1. Is the filler metal and procedure that is adopted capable of penetrating through the mill-scale surface in fillet welding, Fig. 48? If not, the weld metal is separated from the base metal by a layer of scale, which may have been incompletely floated to the surface of the weld.

2. Penetration sometimes is called the depth below the surface to which the fused zone extends, Fig. 49.

3. If the filler rod is deposited in a butt joint, is the weld metal able to flow to the full depth of the joint with the procedure that is adopted? In Fig. 50, the weld metal has failed to penetrate to the bottom. Root chipping and rewelding will be required. Failure to penetrate in this sense is due to a combination of too fast a welding speed and inadequate flux. In order that the weld metal may wash up on the scarf and "wet" it,

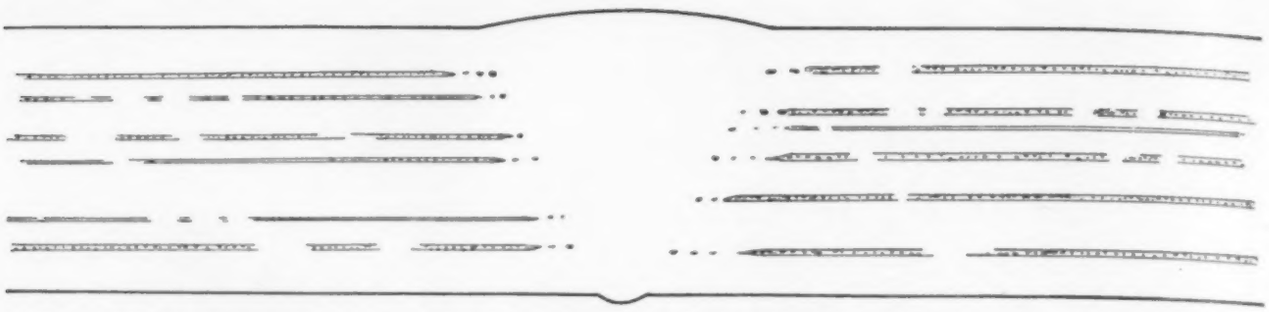


Fig. 51—Schematic Diagram of a Deep-Etched Cross Section of a Fusion Weld in Mild Steel Plate Showing Segregation in the Plate and Its Coagulation and Disappearance at the Weld

the flux must have dissolved the oxide scale caused by welding heat.

Laminations

Slag inclusions in wrought material to be welded occur as fibers, Fig. 51. If the fibers are unusually large they are called laminations. The welding heat melts the fibers in the fusion zone and replaces the fiber by a rounded globule. However, laminations have a strong tendency to open out under the action of welding heat, possibly because SO_2 is evolved. At any rate, welding should not be performed on laminated plate.

The elongated slag inclusions in mild steel account for the difference in properties exhibited by specimens tested with the fibers parallel and perpendicular to the load. If the fibers are perpendicular to the load, the strength and, particularly, the ductility are lower than if the fibers are parallel to the load It is true that steel is usually fabricated so that the major design stress is parallel to the fibers. Nevertheless, "transverse" loading (stress perpendicular to fibers) cannot always be avoided, and in any event, laminations are nearly always cause for complaint. For this reason a homogeneity test is included in A. S. T. M. Specifications for fire-box and several other types of steel. A nick is made in the steel, a hammer blow causes fracture, as in a nick-break test, and the fractured surface "shall not show any single seam or cavity more than $1/4$ inch in length for plates $3/4$ inch and under in thickness." Laminations are entirely distinct from *banded structure*, which is of two types. In one type the pearlite grains in mild steel arrange themselves in long strings or bands in the direction of rolling surrounded by the free ferrite, which is in corresponding bands. The other type of banded structure is created by segregation of phosphorus in bands, which etch less deeply than areas containing less phosphorus and consequently appear like ghosts (white) against a dark, deeply etched background. Pearlite banding has little effect on properties; phosphorus ghosts are undesirable as they indicate high phosphorus content.

Surface Appearance

The appearance of the surface of a welding bead as it is deposited and after cooling often provides a good deal of information. During welding, the metal should not become covered with the thick slag and should not foam or spark. (Sparks are small particles of steel ejected from the weld metal as a gas bubble bursts upon reaching the surface. The small, hot drop of steel burns in the air.) Furthermore, solid beads should contain no cracks and no pock marks left by the bubbles. The rippled surface of the bead is related to the speed of welding (amount of metal deposited in a unit time), welding procedure, and the range of solidification of the steel. Craters often are sources of cracks, because the crater cools more rapidly than the remainder of the bead, and because the crater solidifies from all sides toward the center, thus favoring shrinkage cracks. The shrinkage cracks in craters are related to the drawing away of the solidified boundary metal from the mushy center of the crater.

Pick-Up

Pick-up is the term used to express the intermixing of a filler rod and base metal of different compositions. For example, plain-carbon steel filler rod is deposited between two plates containing $3\frac{1}{2}\%$ Ni. The weld metal will contain perhaps 1% Ni, because some of the base metal has been melted into the weld. The weld metal has *picked up* 1% Ni.

Nitrogen

The weld metal from bare steel electrodes generally contains about 0.1% nitrogen, which is a serious impurity. Weld metal from covered electrodes and from other welding processes is substantially free from nitrogen. The nitrogen in the bare wire weld metal seems to be absorbed from the air in an unexplained way, despite the fact that a thin layer of ferrous oxide covers the bare electrode weld metal. Both nitrogen and oxygen embrittle the weld. Consequently important welds should never be made with bare electrodes.

Questions

1. Why was nitrogen of great importance when bare electrodes were used for welding steel? How may nitrogen pick-up be avoided?
2. The nonmetallic material in a lamination generally melts at a lower temperature than the surrounding steel and may react with the welding atmosphere to liberate gases. Show how these two facts account for the avoidance of laminated steel by welders.
3. Distinguish between the origin of blow-holes and slag inclusions.
4. Show the difference among pipe, segregation and laminations.
5. What factors favor hot cracks while an alloy is in the mushy stage?

AUTOMATIC BRONZE-WELDING*

By ROLAND HAWLEY†

BRONZE-welding or brazing as it is better known is perhaps one of the older forms of uniting two or more parts together. It has a number of very desirable characteristics that haven't been duplicated by any other process. On some jobs that are on a production basis, it is found it can become a slow and tedious operation, depending very much on the human element.

With a little study of the application to be applied, it is possible to design a machine that will do a faster job, deposit the bronze to closer limits and take out the human element almost completely. This is known as automatic bronze-welding.

An attempt will be made to cover the different fundamentals that must be grouped together to make a practical installation. The first point to be studied is how many different applications are there to be done. It is desirable to build a machine to do a number of jobs rather than one, so as to keep it busy. If the volume is great enough then a machine can be built for one application.

In the machine proper it is necessary that a variable speed control of travel be set up so it is possible to increase or decrease the speed of the part being welded at will. Control of rod feed speed is another essential. Another important factor is the carriage or holder for torch assembly that should be designed so that it can be set stationary or cut in to oscillate with control of size and speed of torch tip oscillations. These factors are discussed in a later portion of the paper.

The next item to be studied is torch requirements. Size and shape of tips have an important function, as the width and depth of deposit are controlled with this manipulation.

Rod requirements are next in line. A machine should have provision so that rods can be fed into the machine either in standard lengths or from coils. If coils are to be used it is good practice to have some kind of straightening arrangement to straighten rods as they are fed into the machine.

Fluxing.—This is perhaps the most important part of automatic bronze-welding. There are different means that could be worked out to get flux to the job, but the one found to be the most efficient to date is the use of a liquid flux that can be fed to the work through the acetylene line, and the amount or volume controlled. Since a weld with this process is only as good as the bonding that takes place, the fluxing plays quite an important part. The flux is used essentially to provide a chemically clean surface on the base metal to insure the intimate molecular union or bond between base metal and the bronze-weld metal.

Regulators.—Regulators should be provided that will deliver a steady supply of oxygen and acetylene with the proper pressures, which are predetermined, taking into consideration tip size, etc. We have found that any standard two-stage regulator answers the purpose well.

* Paper presented at the 40th Annual Convention, International Acetylene Association, Milwaukee, Wisconsin, April 10, 11 and 12, 1940.

† Foreman, Welding Department, Oil Gear Company, Milwaukee, Wisconsin.

Preheating.—The size of part as well as the number of pieces to be preheated will settle the question as to what type of preheating furnace, if any, will be needed. On some applications it may become necessary to install preheating torches on the machine to keep the job to the required heat as the work is progressing.

So far, we have covered the study of the fundamentals that are required to build a machine for bronze-welding. Now to go on with operation of an actual machine.

Operation.—The preparation of the part to be welded should be given a little thought. It has been found that the section to be covered should be cleaned by some mechanical means to insure a clean surface on which the bronze is to be applied. The machine should be so designed to hold the part firmly and also for ease of changing from one part to another. After the part has been preheated to proper temperature, it is placed in the machine and properly adjusted. If auxiliary preheating is required to keep the part to the required heat, it should be used accordingly.

Flame Adjustment.—The right type and size of tip should be adjusted as to direction of flame in regard to the work and then flame adjusted from neutral to slightly oxidizing. It will be found at first when the liquid flux is used that the flame will have entirely strange appearance, but after a little experimenting, it will be found easy to adjust to the required flame. It is a good practice to check adjustment of flame from time to time, and, as was mentioned earlier in the paper, the travel or oscillations of the tip should be adjusted. It has been found through experiments that the movements of the tip have a very definite part in automatic bronze-welding. There are a number of variables that enter into the picture at this point. We will go on to another variable and try to tie up several together.

Tinning.—The operation of forming the molecular union or bond between the bronze-weld metal and the base metal is the most important step in bronze-welding. The strength of this bond determines the strength of the bronze-weld joint. Because of the importance of this operation, it is known as "tinning." It requires study. The movement or oscillation of the tip plays an important part as the tinning progresses. The fluxing agent has its part in this and the requirements are that the flux be so controlled so as to get the proper mixture to the tip. The rate or rod feed must be adjusted so that the required amount of deposit will be formed. The feed of the rod must be studied as the rod feeding in has a chilling effect on the weld and must be compensated for by flame control. It will take a little study of the molten puddle if the work happens to be on an inside or outside diameter. If on the inside and puddle is too long, the bronze will have a tendency to run down and pile up under tip; if on the outside, it will run off and the required thickness of deposit will not be maintained.

Desired Physicals.—There are any number of different grades of bronzes on the market today that can be successfully welded. The average compositions of bronze rods on the market today are as follows:

Copper	57–60%	Average	Physicals, Tensile
Silicon	0.19%	Strength	40,000–57,000
Iron	1.25%	Elongation	7–16%
Tin	2.00%	Yield point	33,000–38,000
Manganese	0.75%	Hardness-Brinell	70–124
Zinc	Bal.	Melting point	1650–1630

To sum up, it seems that with a little experiment and study there are a number of different applications that could be successfully applied with a considerable savings in oxygen, acetylene and bronze with a marked increase in production.

Note: The following are average figures representing the control speeds applying to the work under discussion:

Work Travel	5½ inches per minute
Oscillations	45 " " "
Wire Feed	8 " " "

Production Cutting on Automatic Stokers

By S. P. McCRACKEN*

TODAY'S automatic coal stoker compares with the stoker of five or six years ago as today's automobile compares with the automobile of the early days. The stoker of today is smoother looking and better designed. It is fabricated largely of sheet steel instead of cast iron. Mass production justifies the cost of expensive dies for forming the sheet metal into clean-cut functional shapes at low cost.

In line with modern mass production methods, all types of welding and flame cutting are liberally used in pro-

* Chief Engineer, Stoker Division, Peerless Manufacturing Corporation, Louisville, Kentucky.

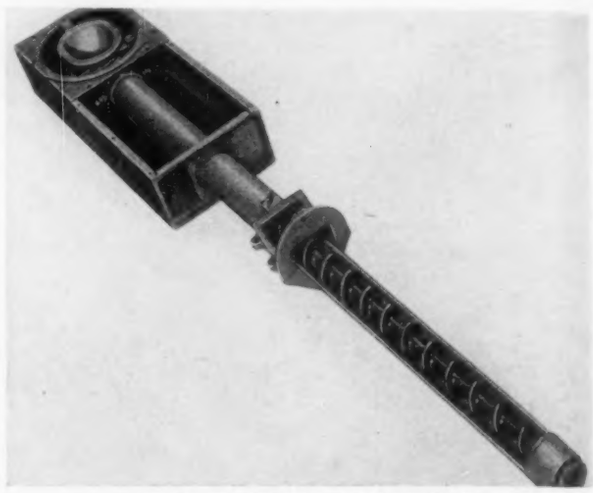


Fig. 1—The "Backbone of the Stoker"

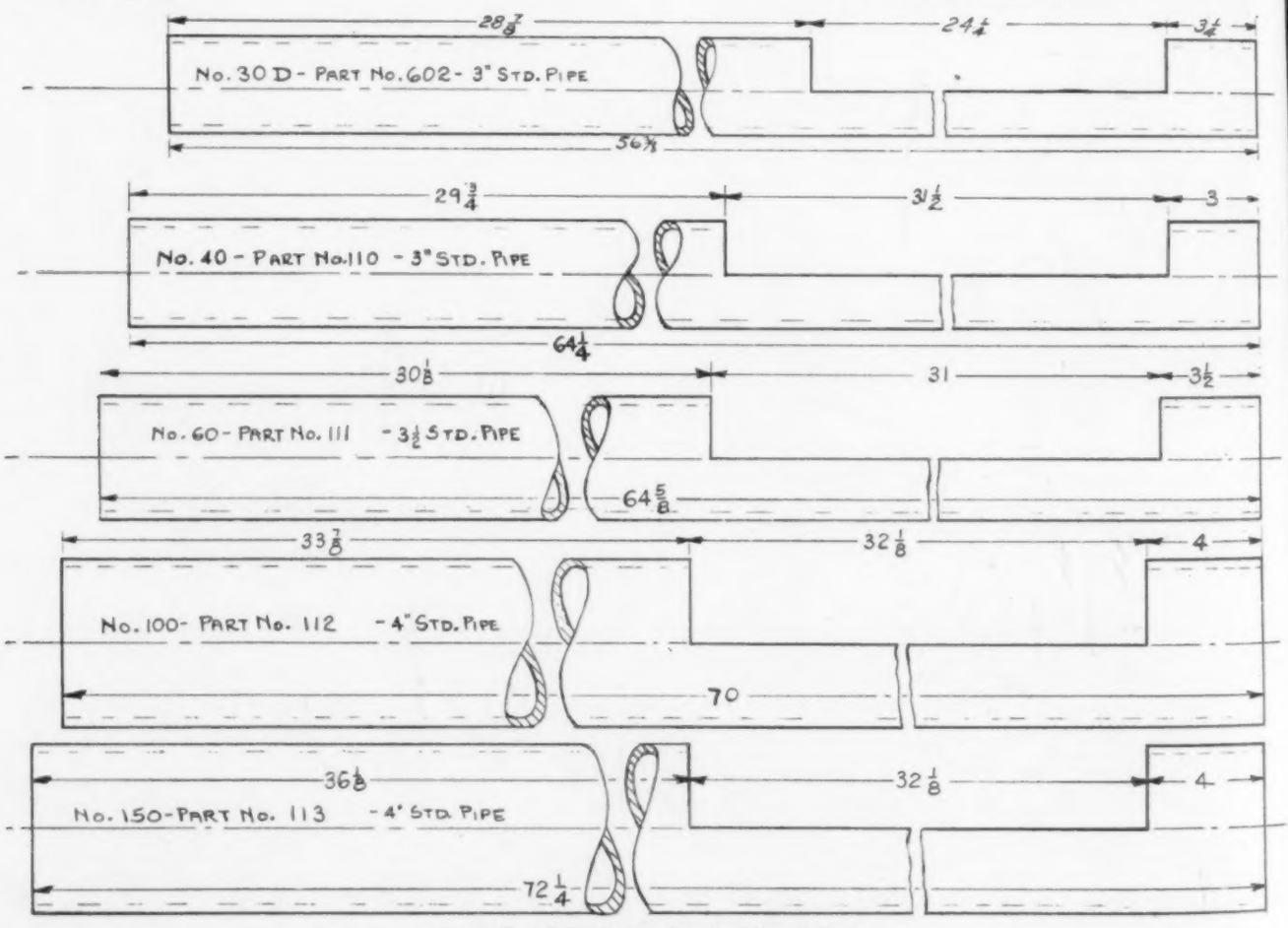
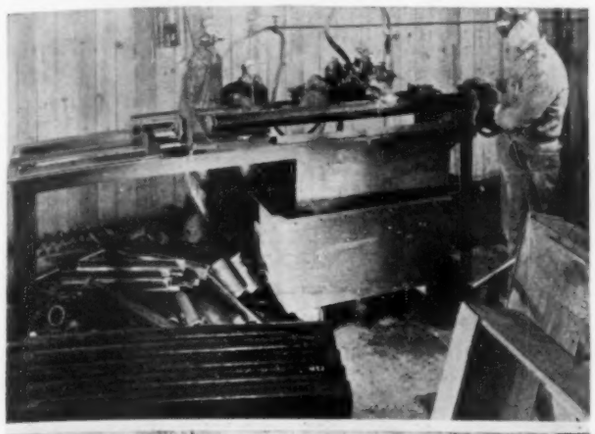
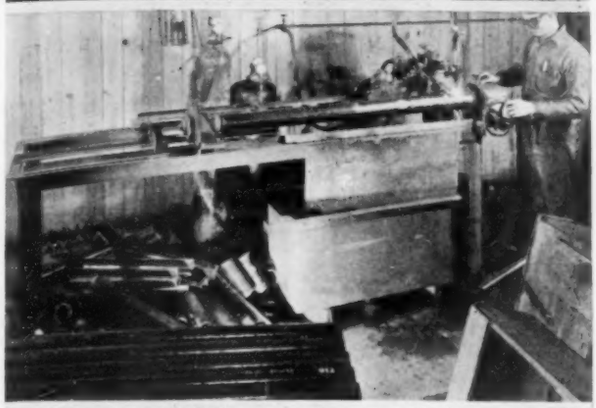


Fig. 2—Feed Tube Cuts for Standard Length Stokers

Fig. 3 (Top)—Cutting Machine Starting Cut Showing Cooling Streams





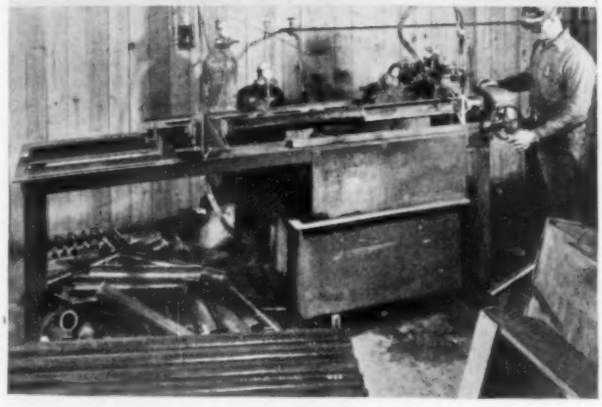


Fig. 4 (Center)—Making Final Cross Cut

Fig. 5 (Bottom)—The Piece Finished

duction and fabrication. Parts which need be merely fastened together are joined by spot welding, while parts which must be put together to form rigid, dust-tight units are assembled by arc weldings. Usually, flame cutting is used to produce parts which are made in too small volume to warrant the expense of blanking dies, but in making the Fire-Guard stoker, we use flame cutting to produce a large production part which is rightly called the "backbone of the stoker" (Fig. 1).

This part which insures absolute alignment of the entire unit and thus makes for low power consumption and high efficiency could not be produced at a cost which would permit its use by any other method. Although it is a very simple part, a piece of standard steel pipe with a section cut out, you can see from the cutting drawing (Fig. 2) how expensive it would be to make the cut on a milling machine, for example. The cut-outs were made at first with a hand torch. Now all sizes of pipe are cut out on a special machine made for the job (Fig. 3, 4, 5).

This machine is built around a standard Radiagraph cutting machine. The pipe is mounted between head and tail stocks with tapered mandrels which will take any of the various diameters of pipe. The head stock can be rotated by the hand wheel through a worm and wheel. The worm wheel which is mounted on the mandrel shaft has stops which limit the rotation to exactly 180 degrees. The Radiagraph travels on tracks parallel to the pipe. Its distance of travel can be

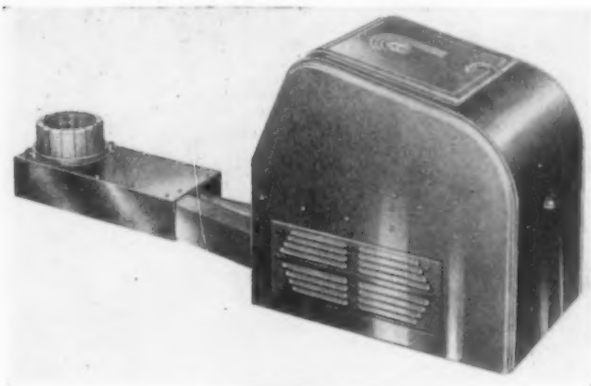


Fig. 6—Final Product

changed for various lengths of cuts in less than a minute by changing the position of the stop tripping rod from one pair of indexed holes in the track to another pair.

An unusual feature of the machine is the provision of coolant to prevent the pipe from warping. Two water pipes are mounted upon the carriage so as to run water on each side of the cut immediately behind the torch.

In operation, the operator after putting the pipe on centers moves the torch over the pipe and throws the switch for forward travel, the machine travels the full length of the cut and stops, the operator rotates the pipe as the torch makes the cross cut, the operator throws the switch for return travel, the machine makes the return cut and the operator rotates the pipe for the cross cut.

The standard piece rates for the various sizes are established on the basis of:

Part No. 602	12 pieces per hour
Part No. 110	10 pieces per hour
Part No. 111	8 pieces per hour
Part No. 112	7 pieces per hour
Part No. 113	7 pieces per hour

With the torch adjusted properly the finished job is as smooth as though it had been sawed out.

Figure 6 shows the final product as assembled around the "backbone." Through the use of this machine, we are able to achieve that which designing engineers are always striving for in mass production, a better product at a lower cost.

POWER SUPPLY FOR RESISTANCE Welding Machines*,†

II. Resistance Welder Installations

PURPOSE OF REPORT

FACTORY wiring and electrical distribution for resistance welding loads must be designed on an entirely different basis than that for the ordinary power and lighting loads encountered in industrial plants. To provide a sound basis upon which recommended methods of wiring, types of bus construction and transformer arrangements can be established, the A.I.E.E. subcommittee on Power Supply for Welding Operations has obtained descriptive reports of a number of commercial resistance welder installations, in plants throughout the country. These reports show the different methods successfully employed in existing installations, and give a clear picture of some of the problems involved. It is hoped that they will serve other users of resistance welding equipment as a basis upon which new installations can be made.

DESIGN PRINCIPLES

In reviewing these reports, it should be remembered that the majority of resistance welding machines have instantaneous kva. demands several times their normal rating, and that in order to prevent excessive voltage drop at this equipment, as well as at any nearby equipment, the supply and distribution facilities must be designed on the basis of the peak kva. demand rather than the normal rating of the machine. From a standpoint of voltage regulation the supply and distribution system must be such as would normally be employed if this peak kva. were drawn continuously. However, due to the low operating duty cycle of this load, its heating effect on the system is usually extremely small.

Since the capacity of all power equipment and distribution systems is based on heating or temperature rise limitations, it is seen, therefore, that in order to serve one resistance welding machine, the normal capacity of the system must be much higher than necessary from a heating standpoint in order to satisfy the conditions of voltage regulation. In fact, in designing a system to supply two or three or even ten welding machines operating on the usual duty cycle encountered, it is safe to neglect the consideration of heating capacity required and design the system to satisfy the consideration of voltage drop. It is only when a considerable number of machines are involved on a single system that the heating becomes a consideration of any importance, or when the duty cycle of a single welder exceeds about 25 per cent, such as with most seam welders.

SUMMARY

In the following representative welder installations, several types of feeder distribution systems are represented. Two of the companies employ a bus system to which the individual welders can be readily and quickly connected or disconnected. Tap points are available at regular intervals and the welding machines can be moved around from season to season with very little expense. The same is true, to a lesser degree, of the wire or cable feeders used by the other companies. This type of feeder does not lend itself quite so readily to frequent changes in plant layout, but is generally cheaper and easier to install.

The bus system employing the concentric arrangement of copper tubes will be found to have the lowest voltage drop, and where this factor is of major consideration this type of feeder is of highest efficiency. In installations where the equivalent thermal loading is high, this type of construction may be unsatisfactory since the heat radiation or conduction from the inside conductor is comparatively low. However, should it become necessary, cooling air can be forced through the inner conductor thus raising its load capacity. The system of interlaced copper bus bars, usually has a high load capacity, but gives a slightly higher voltage drop than the concentric construction.

The system of cable construction is of course the simplest, since the problems of insulation are minimized. In general this type of construction gives a higher voltage drop and lower load capacity than either of the above types. However, if the various conductors are interlaced and spaced very close together the voltage drop can be reduced to a value comparable with the bus type construction. In so doing the load capacity is reduced due to the reduced radiating surface, and this must be compensated for by a sufficient number of parallel lines to reduce the thermal loading to the safe point.

Table 1 shows the ratio of total connected welder load to total supply transformer capacity for the various installations, the ratio of largest single welder to total supply transformer capacity, and the ratio of resultant thermal load to total connected load. The first ratio in some cases may be determined by the thermal loading of the system and thus be dependent upon the average operating duty cycle of the units comprising the installations. If the average operating duty cycle is high, the thermal loading will be high and this ratio must be low. The ratio of largest single unit to supply transformer

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* Prepared by A.I.E.E. Committee on Electric Welding, subcommittee on Power Supply for Welding Operations and presented at A.I.E.E. winter convention.

†Personnel of A.I.E.E. subcommittee on power supply for welding operations: L. W. Clark, Chairman; E. F. Dissmeyer, M. B. Gathman, C. E. Heitman, W. F. Hess, E. A. Hester, H. S. Hubbard, S. M. Humphrey, A. H. Lewis, G. S. Mikhalapov, C. L. Pfeiffer, F. H. Roby, and F. E. Sanford.

Table 1—Summary

Company	Feeder	Phases	Power-Transformer Capacity	Connected Load	Type of Service	Ratio Total Connected Load to Total Supply Transformer Capacity	Ratio Largest Single Welder to Total Supply Transformer Capacity	Ratio of Thermal Load to Total Connected Load
A	....	Three Phase	3000	4,500	Flash	1.5	0.25	0.118
B	*A*	Single Phase	1000	2,000	Projection, flash and seam	2.00	0.50	0.10 for all feeders combined
B	*B*	Single Phase	2000	1,700	Projection and butt	0.85	0.375	0.10 for all feeders combined
B	Top	Single Phase	2000	1,960	Flash and projection	0.98	0.3	0.10 for all feeders combined
B	Center	Single Phase	2000	2,750	Flash and projection	1.375	0.3	0.10 for all feeders combined
B	Bottom	Single Phase	2000	1,250	Projection and flash	0.625	0.3	0.10 for all feeders combined
C	....	Single Phase	1500	13,119	Miscellaneous	8.74	0.3	0.048
D	....	Three Phase	1000	1,500	Seam	1.5	1.5	0.67
D	....	Single Phase	1260	500	Projection	0.4	0.4	0.44
D	....	Single Phase	840	750	Spot	0.89	0.89	...
E	....	Single Phase	666	1,565	Spot and seam	2.35	0.60	...
F	....	Three Phase	1500	2,400	Miscellaneous	1.6	0.267	0.177

capacity is usually determined by the requirements of over-all voltage drop. If a large part of the permissible voltage drop is consumed in the feeder line, the allowable drop in the supply transformer is small, and this ratio must be small. In most commercial installations it is this consideration of voltage drop that determines the supply transformer capacity, rather than the consideration of thermal loading.

It will be noted that the ratio of total connected load to total supply transformer capacity, varies from 0.4 to 8.74, but the weighted average is about 2.0. This wide variation may be partly explained by the fact that the method of rating resistance welding equipment has, in the past, been rather vague, and the values of connected load taken from the nameplate ratings may be quite at variance with the now commonly accepted practice of rating equipment on the basis of a 50% duty cycle. For example under Company *C*, Part VI we see that a normal current of 300 amperes applies to four different sizes of equipment, namely 50, 75, 100 and 150 kva.

The minimum value of 0.4 applies to a projection welder operating from a special supply transformer, and supplied by means of a concentric cable feeder. Obviously the major consideration in this case is that of voltage drop.

The maximum value of 8.74 applies to an installation having a relatively large number of units. In such an installation the probability of a large number of units operating simultaneously is rather remote, so that from a standpoint of voltage drop, the required capacity of the supply transformer bank is determined by the size of the largest single unit. In this instance the ratio of largest single unit to supply transformer capacity is 0.4.

Another factor which makes for low supply transformer capacity, in this case, is the use of the low impedance concentric tubular bus. This type of bus gives a comparatively low voltage drop, so that a higher impedance (lower capacity) supply transformer bank can be tolerated. The chief reason for the ability of Company *C* to serve 13,119 kva. of welding load with only 1500 kva. of supply transformer capacity, is their use of a good concentric bus design with extremely low impedance. This permits serving an exceptionally large factory area by the single bus system without obtaining excessive voltage drop at the welding equipment. Other types of bus construction and cable assemblies cannot serve as large an area, nor as many units, without excessive voltage drop. The result is that where such construction is used there must be more feeders operating in parallel or a higher supply transformer capacity.

Where a large number of smaller units are to be served, the thermal loading of the supply transformers and feeder lines may become the determining factor. This determination, however, depends upon a knowledge of the operating duty cycles of the various equipments. In this particular case the average operating duty cycle is comparatively low, the ratio of average kva. load to connected kva. load being 4.8%. The ratio of average kva. load to supply transformer capacity is approximately 0.4, the extra capacity being necessary to limit the voltage regulation.

The ratio of largest single unit to supply transformer capacity varies from 0.3 to 1.5, with a weighted average of about 0.5. The maximum value of 1.5 applies to a seam welder installation in which the thermal loading of the system is the determining factor in selecting supply transformer capacity.

The ratio of thermal load to total connected welder load for these commercial installations of all types except seam welders is between 0.048 and 0.177, and for seam welders, between 0.44 and 0.67.

It must be remembered that it is impossible to give any definite empirical values for any of these ratios, since the proper values depend upon individual conditions. The values given in Table 1 do however give a general idea as to the practice followed in some of the industry's successfully operating installations.

It is interesting to note that in all of these installations overload protection of the feeders and transformers, is confined to instantaneous over-current devices, designed to protect against short circuits. In one installation this instantaneous tripping is reduced well below the short circuit current to provide a measure of protection against high overloads on individual welders. The protection thus afforded against individual machine overloads is very small. In so far as we are informed, the only practical overload protection is that afforded in the connections to each individual machine. This may take the form of instantaneous over current trips, over-time trips, or a combination of these two, or some thermal relay or fuse with thermal characteristics similar to the equipment to be protected.

For the protection of supply transformers, the instantaneous over-current devices set for short circuit currents have proved satisfactory. In installations where the thermal loading is high, contact making ther-

mometers immersed in the cooling oil have been employed to trip the circuit breakers when the oil temperature becomes excessive.

Another point of interest is that the power supply for the resistance welding loads is usually separated from the general plant power supply. Generally speaking the voltage disturbances produced by the resistance welding load cannot be tolerated on other plant loads, particularly lighting. For this reason an attempt is made to minimize these disturbances by separating the two loads as much as possible.

INSTALLATIONS

Company A—Installation

I. *Method of Service by the Power Company*

The power company provides service for all plant load, including the resistance welders through a stepdown substation consisting of two 6000 kva., three-phase transformers connected 24,000/2400 volts, located on the plant property as near as practicable to the load. Each transformer is radially fed by means of an underground cable from a 24,000-volt substation located about $^1/_4$ mile from the plant. The transformer secondaries are solidly connected to the 2400-volt bus. The 2400-volt plant feeders are connected to the bus through oil circuit breakers and double throw disconnects, as shown in Fig. 1.

II. *Cost to the Power Company to Serve Welder Load*

No special consideration or expense was required by the power company to serve the welder load. The stepdown substation was needed to supply the load at the voltage required, and the 24,000-volt supply to the substation was of ample capacity to take the kva. swings of the welder without producing troublesome flickers.

No other customers are fed from this stepdown substation and so the power company has not been concerned by the flicker on the 2400-volt bus. If, in the future, some new load develops in this area that could advantageously be fed from this substation, it might be necessary to set aside one substation transformer for welders and other flicker producing load and use it also as the throwover.

III. *Plant Distribution for Welders*

The welder power transformers which supply the welder bus are three 1000 kva., single phase, 2400/480 volt, 4.4 per cent impedance, connected delta-delta in a three-phase bank. They are fed from the primary room by three 250 ft. lengths of 500 M-circular mil three conductor cables, operating in parallel. The transformers are located on the roof near the load center of the welders. The 480-volt transformer bus is made up of two $^1/_4$ x 4-inch copper bars per phase. Solidly connected to the transformer bus are twelve three-phase feeders of three single conductor, 500 M-circular mil cables distributed over the entire bus. These feeders are brought down from the transformer bus on the roof to the welder room in four groups of three three-phase feeders. Each group is supported in wooden cleats and taped together. In the welder room, the four groups of three feeders divide into two groups of six feeders each. One group extends about 80 feet east and the other about 160 feet west from the transformer bus. The three conductors of each three-phase feeder are taped together and supported from messenger cable strung from the building girders above the line of welders. Each welder is connected to the same phase of each of the six three-phase feeders so as to divide the load about equally among the six feeders.

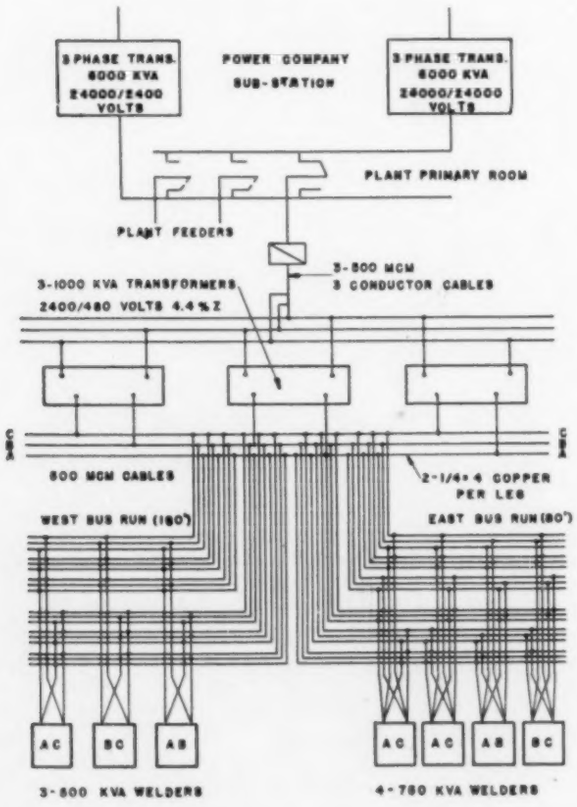


Fig. 1—Schematic Diagram of Welder Supply System—Company A

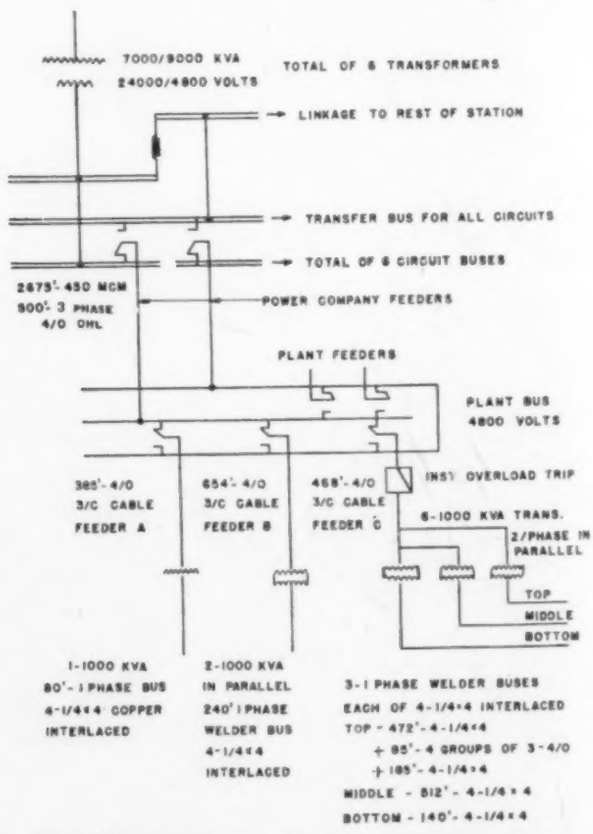

7000/9000 KVA
24000/4800 VOLTS
TOTAL OF 6 TRANSFORMERS
LINKAGE TO REST OF STATION
TRANSFER BUS FOR ALL CIRCUITS
TOTAL OF 6 CIRCUIT BUSES
2673'-450 MCM 600-3 PHASE 4/0 OHL
POWER COMPANY FEEDERS
PLANT FEEDERS
PLANT BUS 4800 VOLTS
385'-4/0 3/C CABLE FEEDER A
654'-4/0 3/C CABLE FEEDER B
468'-4/0 3/C CABLE FEEDER C
INST. OVERLOAD TRIP
6-1000 KVA TRANS. 2/PHASE IN PARALLEL
TOP
MIDDLE
BOTTOM
1-1000 KVA 80'-1 PHASE BUS 4-1/4"x4 COPPER INTERLACED
2-1000 KVA IN PARALLEL 240' 1 PHASE WELDER BUS 4-1/4"x4 INTERLACED
3-1 PHASE WELDER BUSES EACH OF 4-1/4"x4 INTERLACED
TOP - 472'-4-1/4"x4
+ 85'-4 GROUPS OF 3-4/0
+ 185'-4-1/4"x4
MIDDLE - 812'-4-1/4"x4
BOTTOM - 140'-4-1/4"x4

Fig. 2—Schematic Diagram of Welder Supply System—Company B

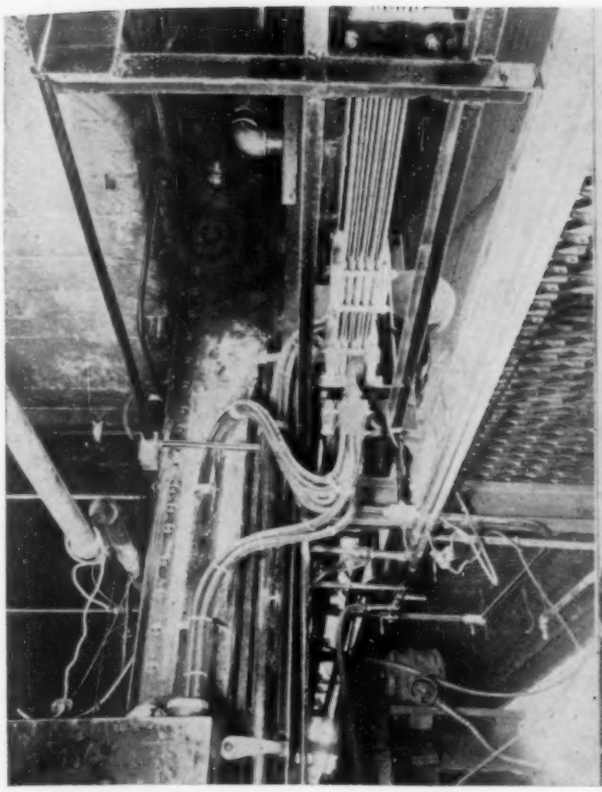


Fig. 3—The Interlaced Welder Bus Used by Company B, Showing Construction and Method of Making Taps for Individual Welders. Bus Consists of Four 1/4 x 4-Inch Copper Bars on 1-Inch Centers, Insulated by Means of Five 1/8 x 6-Inch Micarta Strips

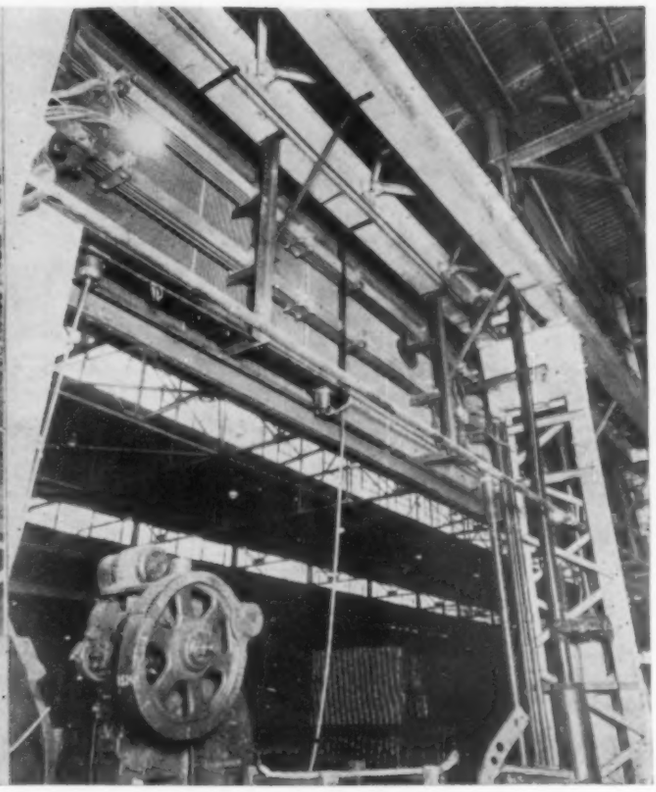


Fig. 4—Two Separate Interlaced Welder Busses Used by Company B, Showing Method of Support

The different welders are connected to the three phases so as to have about an equal load division on the three phases.

IV. *Cost Data on the Welder Feeder*

Low cost was obtained by the use of the same size copper (500 M-circular mil) throughout.

V. *Welder Feeder Protection*

All connections are solid from the oil circuit breakers in the primary room to the welder. The oil circuit breaker is automatic and set for time delay trip on overload.

VI. *Type and Rating of Welders*

The welders are all flash welders of which four are rated 750 kva. and three are rated 500 kva.

VII. *Voltage Drop*

Voltage drop data given below are calculated values based on a single-phase load of 800 kva. of welding current at 0.4 power factor 480 volts.

1. At 24,000-volt bus in power company substation.....0.7%
2. At 2400-volt bus in plant switch house...2.3%
3. At 480-volt transformer bus.....4.7%
4. At welder, including 65-foot welder bus...5.0%

The voltage drop for the above four items is accumulative and represents the total drop to each point. To find the drop in any particular part of the system, for example, the drop from the 480-volt transformer bus (item 3) to the welder over 65 feet of bus (item 4) is 5.0% minus 4.7% equals 0.3%.

VIII. *Equivalent Thermal Loading*

The heating load on the welder feeder obtained by maximum demand, heater type, ammeters was approximately 128 amperes per phase at 2400 volts, which was 530 kva. The heating load in per cent of total connected welder kva. is 530/4500 equals 11.8%. At the time these readings were taken, it was known that only 3500 kva. of welders were actually operating. The heating load in per cent of operating welder kva. was 530/3500 equals 15.2%.

Company B—Installation

I. *Method of Service by the Power Company*

This plant is fed by two 4800-volt power lines out of a 24,000/4800-volt stepdown substation as shown in Fig. 2. The stepdown substation consists of six 7000/9000 kva., 24,000/4800-volt three phase, radially fed transformers, serving six 4800-volt circuit buses. Each transformer is linked to the rest of the substation through reactors and a linkage bus. The circuit buses occupy the lower position of a double bus arrangement with a transfer bus above. The transfer bus is a continuous section energized from the linkage bus.

The plant primary room bus is also a double bus arrangement with a power line feeding each bus. The welder feeders are operated on the throw over bus and general plant load on the other bus.

II. *Cost to the Power Company to Serve Welder Load*

Originally the power line supplying the welder load was connected to a circuit bus at the substation with only power load. On such a bus the flicker limit is three volts (at lamp voltage) which would permit 1500 kva. load swings. The plant later increased the size and number of welders until load swings exceeded 2000 kva. and caused voltage flickers of four to five volts, and complaints from other customers on this bus.

There were sufficient spare positions at the substation so that it was possible by rearranging and transferring lines to set aside one circuit bus for this welder load. At present this circuit bus carries only the load of this one power line, but the transformer is still connected to the other buses through the linkage. If the load in this substation area increases and the spare positions on this bus are needed for new load, it may be that enough of this new load will be flicker load to provide satisfactory loading for the transformer. This has happened at other substations where a bus has been set aside for special load. Another alternative might be to use the spare positions on this bus as throwover lines to other customers. It is not felt in this case that the power company has been put to any appreciable added expense to serve this welder load.

III. *Plant Distribution for Welders*

The welding transformers are located at three different parts of the plant and are supplied by three 4800-volt feeders from the primary room. Feeders *A* and *B* (Fig. 2) serve general plant load as well as welders, while Feeder *C* serves welder load only. The welders are tapped to single phase 480-volt buses made up of four $^1/_4$ x 4-inch copper bars with the going and return bars interlaced on 1-inch centers with a micarta spacer between each bar and on each side of the entire assembly as shown in Fig. 3. The bus is of open construction supported from the building pillars shown in Fig. 4. To reduce the chance of short circuits from foreign material falling across the bars, the micarta spacers extend about 1 inch above the bars. Data on each of the feeders are given below:

Feeder *A*

1—350 feet of three conductor, 4/0 cable from primary house to transformer.
2—Supply transformer—one 1000 kva., single phase, 4800/480 volt, 4.6 per cent impedance.
3—Feeder bus—80 feet of four $^1/_4$ x 4-inch copper bars interlaced.

Feeder *B*

1—654 feet of three conductor, 4/0 cable from primary house to transformers.
2—Supply transformers—two 1000 kva., single phase, 4800/480 volts, 4.6 per cent impedance, two in parallel.
3—Feeder bus—240 feet of four $^1/_4$ x 4-inch copper bars interlaced.

Feeder *C*

1—468 feet of three conductor, 4/0 cable from primary house to transformers.
2—Supply transformers—six 1000 kva., single phase, 4800/480 volt, 4.6 per cent impedance (two transformers in parallel on each phase).
3—Feeder bus
Top bus—472 feet of four $^1/_4$ x 4-inch copper bars interlaced plus 85 feet of four interlaced groups of three 4/0 cables, each on about 4 inch centers to another bay and there 185 feet of four $^1/_4$ x 4-inch copper bars interlaced.
Center bus—512 feet of four $^1/_4$ x 4-inch copper bars interlaced.
Bottom bus—140 feet of four $^1/_4$ x 4-inch copper bars interlaced.

IV. *Cost Data on Welder Feeder*

The welder bus cost was $10.50 per foot installed.

V. *Welder Feeder Protection*

There is no protection provided on Feeders *A* and *B*. The oil circuit breakers in the primary room are non-automatic. The oil circuit breaker of Feeder *C* is automatic and set for instantaneous tripping on overload. The power company's incoming line is also provided with an automatic instantaneous tripping oil circuit breaker, so it is doubtful if a worthwhile degree of selectivity is obtained between the plant Feeder *C* breaker and the power company's breaker.

VI. *Type and Rating of Welders*

The type, number and rating of the welders on each bus are given below:

Feeder *A*

Projection, flash and seam	6
Total connected load	2000 kva.
Largest single unit	500 kva.

Feeder *B*

Projection and butt	9
Total connected load	1700 kva.
Largest single unit	750 kva.

Feeder *C*

Top Bus

Projection and flash	11
Total connected load	1960 kva.
Largest single unit	600 kva.

Center Bus

Projection and flash	11
Total connected load	2750 kva.
Largest single unit	600 kva.

Bottom Bus

Projection and flash	3
Total connected load	1250 kva.
Largest single unit	600 kva.

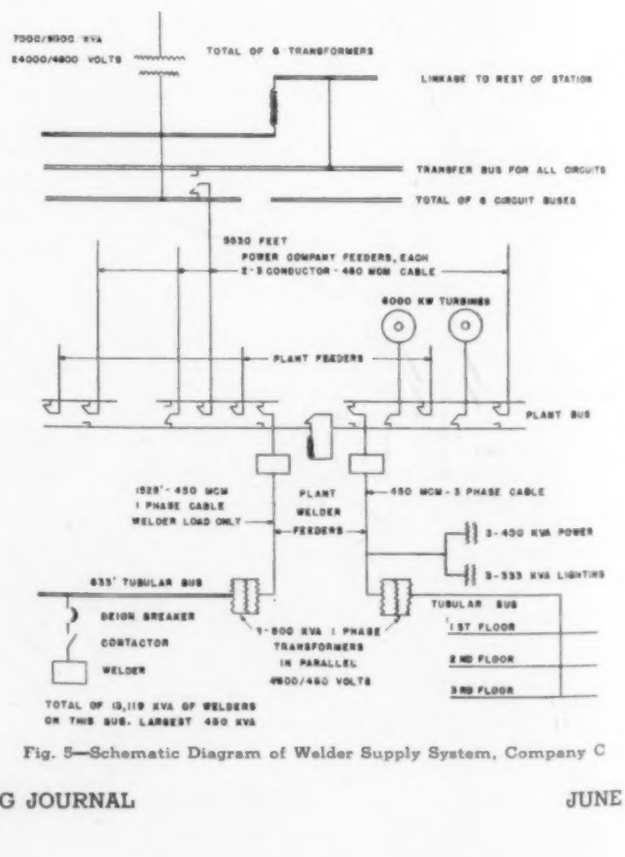


Fig. 5—Schematic Diagram of Welder Supply System, Company C

Fig. 6—The Concentric Tubular Bus Used by Company C, Construction and Method of Support. The Bus Is Made Up of Bare 4-Inch Standard Copper Tubing Over a 3-Inch Extra Heavy Tube with a Micarta Tube Separator. Taps for the Individual Welders Are Provided Every Six Feet

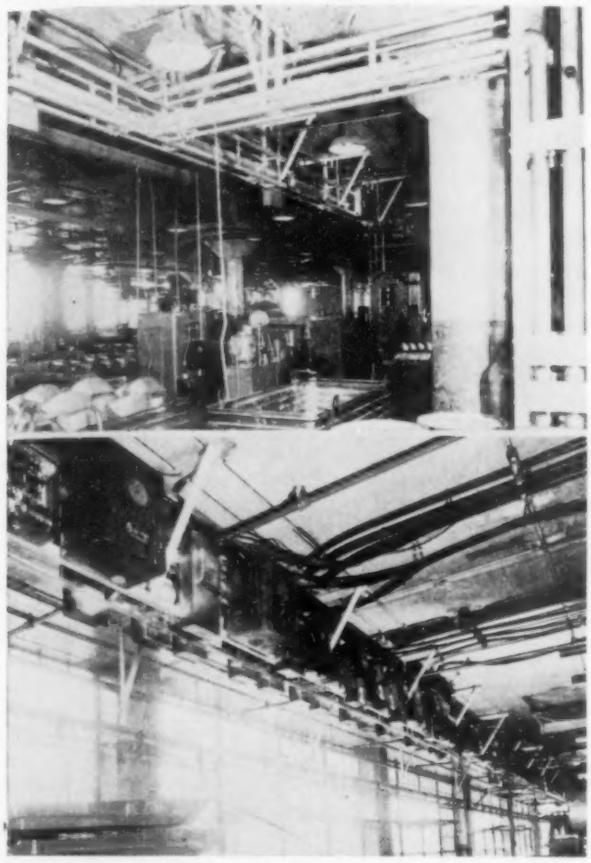


Fig. 7—Showing Welder Bus and Controls Used by Company C. The Controls Are Mounted on Racks Alongside the Bus, and Consist of De-Ion Circuit Breakers, Welding Contactor and Timer for Each Welder

Test data has been obtained on two of the largest welders used.

1—600 kva. Projection Welder
Maximum swings—960 kva., 2110 amperes, 450 volts at 0.347 power factor at welder (1000 kva. at substation).

2—750 kva. Welder
Maximum swings—1760 kva., 4300 amperes, 418 volts at 0.299 power factor at welder (2100 kva. at substation).

VII. *Voltage Drop Caused by Welder Load*

The voltage drop at various points has been calculated and is based on a load of 2100 kva. at 480 volts 0.4 power factor.

1. At substation 4800-volt bus..... 3.5%
2. At plant primary room 4800-volt bus... 6.4%
3. At welding transformer primary..... 7.1%
4. At welding transformer secondary (two 1000 kva. in parallel).....11.8%
5. At welder over 100 feet of four $^1/_4$ x 4-inch bus.....13.0%

The voltage drop for the above five items is accumulative and represents the total drop to each point. To find the drop in any particular part of the system, for example, the drop from the welder transformer secondary (item 4) to the welder over 100 feet of bus (item 5) is 13.0% minus 11.8% equals 1.2%.

VIII. *Equivalent Thermal Loading*

There are no available data on thermal loading on the individual feeders. For the total connected load of 9660 kva., the average kva., or thermal load is approximately 900 kva., or slightly less than 10%.

Company C—Installation

I. *Power Company Method of Service*

The stepdown substation from which this plant is fed consists of six radially fed three-phase transformers of 7000/9000 kva., 24,000/4800 volts, feeding six 4800-volt circuit buses as shown in Fig. 5. The transformers are linked by reactors on the 4800 volt side. The circuit buses and transfer bus form a double bus arrangement, with the transfer bus tied to the linkage bus. The short circuit kva. on each 4800-volt circuit bus is 147,000 kva.

Each power line to the plant consists of two cables of 450 M-circular mil and supplies a separate bus at the plant primary house. In addition to the power company supply, there are two 6000 kw. turbines at the plant which operate in parallel with one power company line.

II. *Power Company Cost to Serve Welders*

The substation bus supplying this plant can stand 1500 kva., swings without exceeding the flicker limit of three volts on the substation bus. This limit has never been exceeded, and so there has been no additional expense to serve the welder load.

III. *The Welder Feeders*

There are two welder feeders, but since their construction is nearly identical detailed description will be given for only one of the feeders.

This feeder consists of 1525 feet of 450 M-circular mil, single phase cable from the primary house to three 500 kva, 4800/480-volt transformers connected in parallel. The 480-volt welder bus is connected solidly to the transformer secondary and extends about 633 feet through the factory and serves a large number of production type welders. The bus is copper tubing made up of a 4-inch standard tube over a 3-inch extra heavy tube with a micarta tube separator. The outer tube is bare, solidly grounded, and supported by the building girders (Fig. 6). There is a tap provided on the bus every six feet. The de-ion breaker contactor and timer for each welder are located on a rack by the welder bus (Fig. 7). The lead into each welder is made of special cable with the control wiring laid in the main cable. This cable required no conduit.

IV. *Welder Bus Cost*

The cost of the tubular bus, made up of 4-inch standard tubing over 3-inch extra heavy tubing in twelve foot sections with taps every six feet is about $9.00 per foot. Installation cost is extra and will depend somewhat upon local conditions.

This company uses 2-inch standard tubing over $1^1/_4$ inch extra heavy tubing on the branches of the second welder bus, but no figures are available on its cost.

V. *Bus or Feeder Protection*

Faults on the welder bus or the 4800-volt supply are cleared by the oil circuit breaker at the primary house. The breaker is tripped after a time-delay by an induction type over-current relay and is selective with the main supply breaker from the power company. Each welder tap has a de-ion type air breaker which is a two-pole breaker with the poles in parallel. This gives it a rat-

ing of 190 amperes and an interrupting rating of 10,000 amperes. The breaker is set for instantaneous tripping at about eight to ten times the breaker rating. The thermal trips were found to be unsatisfactory and have been disconnected.

VI. *Type and Rating of Welders Served*

This feeder serves a total of 13,119 kva. of welders of various types and ratings. The list given in Table 2 is fairly representative of the types and sizes served:

VII. *Equivalent Thermal Loading of Bus*

The following readings were obtained during normal production on the feeder which supplies welders only.

Connected kva	13,119
Normal peak kva	860
Average load kva	610
Average load kw	304
Average power factor	304/610 = 49.8 per cent
Average kva./Connected kva.	610/13,119 = 4.8 per cent

VIII. *Voltage Drop Caused by Welder Load*

1. At the substation bus 4800 volt..... 2.5%
2. At the plant primary house 4800 volt... 3.8%
3. At the welder transformer primary 4800 volt..... 4.5%
4. At the welder transformer secondary 480 volt..... 8.7%
5. At the welder over 633 feet of bus.....11.3%

The above figures are calculated for 1500 kva., 0.4 power factor, 480 volt welder load supplied by one power company line and do not take into account any assistance obtained from the plant generators.

The voltage drop for the above five items is accumulative and represents the total drop to each point. To find the drop in any particular part of the system, for example, the drop from the welder transformer secondary (item 4) to the welder over 633 feet of bus (item 5) is 11.3% minus 8.7% equals 2.6%.

Company D—Installation

There are at present 269 resistance welders installed in this plant, with the following nameplate ratings:

51—Welders each rated under	5 kva.
70—Welders each rated under	5 to 25 kva.
25—Welders each rated under	30 to 50 kva.
60—Welders each rated under	60 to 100 kva.
26—Welders each rated under	125 to 175 kva.
26—Welders each rated under	200 to 300 kva.
6—Welders each rated under	350 to 400 kva.
1—Welder each rated under	500 kva.
2—Welders each rated under	600 kva.
1—Welder each rated under	750 kva.
1—Five head welder rated	1500 kva.

Electronic control is used wherever accurate timing and synchronous switching is required. In installations requiring less accurate control, Ignitron contactors are now being used in place of the former standard magnetic contactor in order to cut down service costs.

Practically all the welders are at present protected by enclosed fused switches. Where control equipment and switch are located at a distance from the welder, it is customary to also include a line contactor operated from a tumbler switch at the welder. In future, however, enclosed air circuit breakers will be used with all but the smaller units. These breakers will be either manually or electrically operated, depending on their location in respect to the welders, and will have instantaneous overload trips, in some cases with an additional under-voltage trip coil operated by a thermal overload relay incorporated in the welder control.

Table 2—Type and Rating of Welders—Company C

Type	Kva. Rating	Normal Current	Maximum Current	Rated Current at Rated Volts
Gun	50	150	550*	114
Gun	75	300	500	170
Hydromatics	100	300	550*	228
Hydromatics	150	300	800*	340
Spot and projection	450	5000	6000*	1000
Spot and projection	50	300	650*	114

* Estimates based on test readings. This company generally figures five to eight times rated kva. for momentary load.

From the standpoint of power supply, these welders may be divided into three classes, as follows:

Class I

This includes resistance welders of all types, both with and without Electronic control, which are installed as separate units and obtain power from the regular 575-volt, 3-phase, 60-cycle shop lines. With the exception of a few spot or projection welders, the nameplates of which may be as high as 350 kva., these welders are not rated over 150 kva. or, in the case of multiple head machines, the individual welding heads do not exceed this limit. About 94% of the resistance welders are in this class.

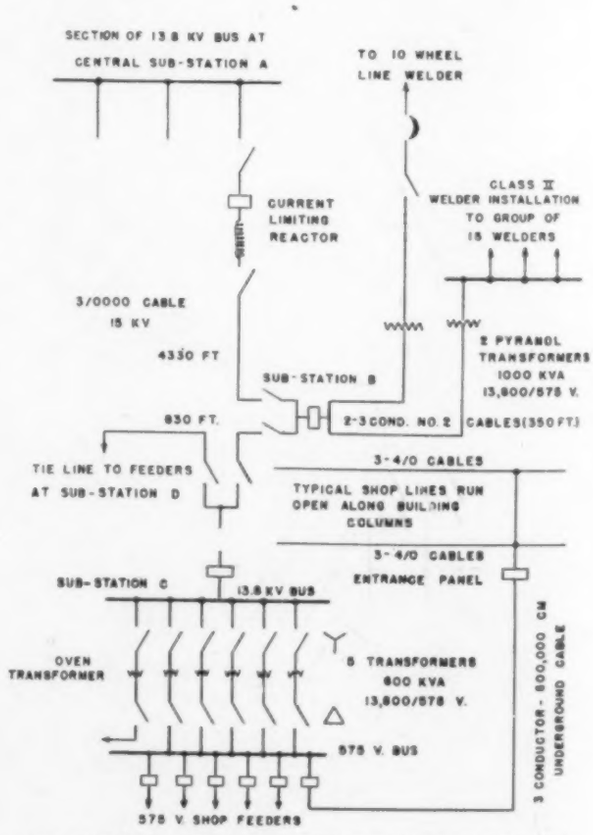

SECTION OF 13.8 KV BUS AT CENTRAL SUB-STATION A
TO 10 WHEEL LINE WELDER
CURRENT LIMITING REACTOR
CLASS II WELDER INSTALLATION TO GROUP OF 15 WELDERS
3/0000 CABLE 15 KV
4350 FT
2 PYRANOL TRANSFORMERS 1000 KVA 13,800/575 V.
SUB-STATION B
630 FT.
2-3 COND. NO. 2 CABLES (350 FT.)
TIE LINE TO FEEDERS AT SUB-STATION D
3-4/0 CABLES
TYPICAL SHOP LINES RUN OPEN ALONG BUILDING COLUMNS
3-4/0 CABLES
ENTRANCE PANEL
SUB-STATION C
13.8 KV BUS
OVEN TRANSFORMER
5 TRANSFORMERS 600 KVA 13,800/575 V.
575 V. BUS
575 V. SHOP FEEDERS
3 CONDUCTOR - 500,000 CM UNDERGROUND CABLE

Fig. 8—Schematic Diagram of Typical Welder Supply System, Company D

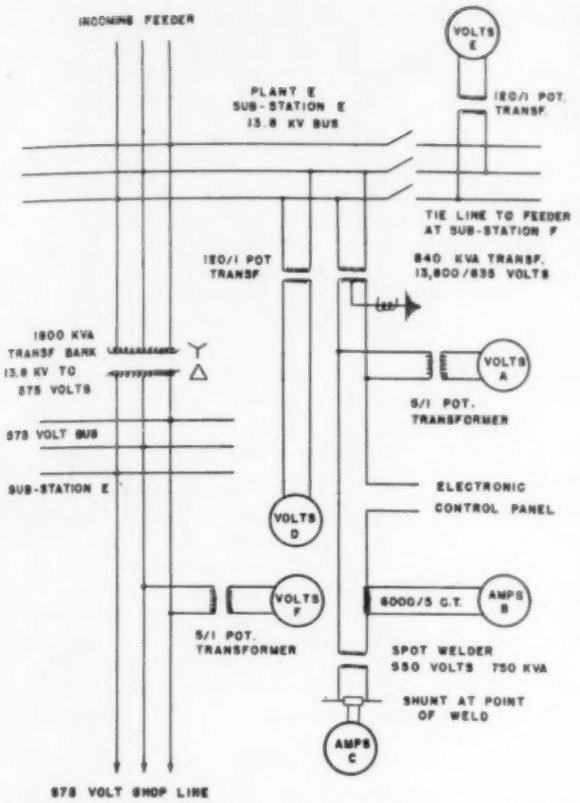


Fig. 9—Location of Voltage and Current Readings Taken During Test of Power Supply System with 750 Kva. Spotwelder in Operation, Company D

Before connecting a welder to a shop line, consideration is given to the effect of voltage drop, caused by the actual power demand during weld, on other load supplied by that line. Inasmuch as most of the lighting load is on D. C. or separate A. C. lighting feeders, it is possible to permit fairly large momentary voltage variations on the A. C. shop feeders without undesirable results. Figure 8 shows a typical section of the 60-cycle distribution. This distribution system is designed to supply shop load, and neither its cost nor design has been directly affected by welders of this class.

The central substation A from which the primary feeders of this system radiate, has a capacity of 30,000 kva. with a calculated bus short circuit value of 500,000 kva. Primary power is distributed at 13.8 kv. 3 phase, grounded neutral, over 17 feeders, most of which are rated 4800 kva. and consist of 3 conductor 4/0 15 kv. cable. Each feeder has a 5% current limiting reactor which limits feeder short circuits to approximately 100,000 kva. Relaying of feeder oil circuit breakers is for short circuit protection only. These feeders serve 24 substations each of which has an emergency tie to at least one other than its normal feeder.

Substations vary from 1800 to 3500 kva. in transformer capacity, the more recent transformer units being 1500 kva. instead of the 600 kva. shown in Fig. 8. Although the 800 amp. 600-volt manually operated oil circuit breaker has been standard for 575-volt feeder protection, air circuit breakers will be used in any new substation construction. This also applies to shop entrance panels.

Secondary feeders are 575-volt, 3-phase ungrounded, and consist usually of one three conductor 500,000 cm. cable nominally rated 400 kva. If more capacity is needed a similar cable is added in parallel or a separate feeder is established. Length of feeder between substation and building may be up to 1000 feet. Inside building feeders usually are of open construction extending the length of the building and may be anywhere from No. 0000 to 1,000,000 cm. in size. It is obvious that the larger welders in this class cannot be fed from the more remote sections of the shop 575 volt lines, and as mentioned above, each case must be considered in the light of the particular line capacity and demand involved.

Class II

This covers group installations of welders where the voltage disturbances set up by the operation of one or more of the welders, if from the shop 575-volt lines, would interfere with the operation of other welders of the same group. In some cases such installations can be supplied from the nearest substation through a special low impedance line, but in two installations, the following methods have been used.

The first group consists of 14 seam welders and one projection welder four of them having 2 welding transformers each (Fig. 8). Nameplate rating of the group is 2524 kva., 550 volt. The 19 electronic controls required, together with their protective equipment, are mounted together on a centrally located overhead platform. Directly below the platform is installed a Pyranol-filled transformer rated 1000 kva. 13,800-575 volts. The low side of this transformer is connected to a short bus directly underneath the platform floor, from which connection is made through 2-pole fused enclosed switches to each separate welder and control. Each welder control is also equipped with a 2-pole contactor, operated from a tumbler switch at the welder, which opens the power circuit to the welder without removing control voltage from its control panel. With all welders operating under normal production, the actual load, as measured with indicating instruments, is 1116 kva., 3 phase, with a maximum unbalance between phases of 12½%, and an average 0.45 power factor. (Note that these are short throat welders). Bus voltage averages 549 volts with a maximum variation plus and minus of 3½%. It is probable that the average kva. load over a period of several hours is slightly below the measured amount which may explain why there is no trouble with overheating the 1000 kva. power transformer.

A second installation directly adjoining the above, consists of one seam welder equipped with 5 welding heads each with a 300 kva. nameplate rating. Control consists of Electronic panels mounted on an extension of the above mentioned platform. Power is obtained from a second 1000 kva. 3-phase Pyranol-Transformer similar to the one mentioned above and located directly below the platform. The low side of this transformer is connected through a manually operated disconnecting switch and a 1200 amp., 3 pole, inverse time limit, electrically operated, enclosed air circuit breaker directly to the 5 welding circuits and controls. Excitation for the controls is fed through an enclosed fused switch tapped into the line ahead of this breaker so that the breaker, which is operated from a push button station at the welder, may be opened without breaking the control excitation. Under normal operation this welder demands approximately 1500 kva. with a 66% duty cycle (2 cycles on, 1 off) and draws, as measured with indicating instruments, 1006 kva., 3 phase, with a maximum unbalance between phases of 22% and an average 0.50 power factor. Supply voltage averages 525 volts with the welder in operation, and 550 volts at no load, with a plus and minus variation at either point of 2%.

The primary power supply to these two installations is taken from one of the regular shop 13.8 kv. feeders *A* indicated in Fig. 8.

The control panel for the 13.8 kv. oil circuit breaker is located on the welder control platform. Connection to the high side of each transformer is through pothead type terminals which in turn are protected by an additional steel enclosure.

Class III

This includes large electronically controlled projection or spot welders where, although the equivalent continuous load is not great, the line current demand at the time of making the weld is so high that it is inadvisable to supply it from the regular power transformers of one of the shop substations. In general, this applies to welders having a demand in excess of 2000 amps. root mean square, 550 volts during weld.

There are at present two installations that illustrate this classification. The first is a Projection Welder rated 550 volts 500 kva. (50% duty cycle). Power for this welder is brought through a 2 conductor, 750,000 cm. concentric cable 500 ft. long, from a special transformer. This transformer is rated 1260 kva. 13,800-287.5/575/1150 v., and is designed to supply 15,000 amps. (Peak) when connected for 575 volts. Maximum current obtainable at the welder is 2200 amps. root mean square during weld with about 70 volts drop in the line.

The second welder in this class is a spot welder with nameplate rating of 550 volt, 750 kva., equipped with electronic control arranged for interrupted operating welding. Power is obtained from a special transformer rated 840 kva. 13,800-635 v. and designed to give an impedance drop of less than 15% when loaded at 6000 amps. 0.60 power factor. This transformer is located outside the building about ten feet from the welder and is fed from the 13.8 kv. bus of the nearest shop substation through 2 lines of a 3 conductor, 15 kv. underground cable approximately 210 ft. long. This substation is in turn fed by a 13.8 kv. feeder 3800 ft. in length, similar to the one shown in Fig. 8. Protection for both the welder and the power transformer is by an oil circuit breaker located in the shop substation and controlled from a panel adjacent to the welder. Both thermal and instantaneous overload relays are provided. Also the midpoint of the 635 volt winding of the power transformer is grounded through a current transformer which operates an instantaneous relay of low current setting to trip the circuit breaker in the event of a ground in either the welder transformer or control. The low side of the power transformer is directly connected to the control and welder through a 2-pole manually operated disconnecting switch.

Recently tests were made to show the effect of the operation of this welder on various parts of the power system. The welder was operated at maximum capacity with a duty cycle of 4 cycles on and 54 off. All readings were taken simultaneously on an oscillograph with the following results. Figure 9 indicates the points at which these readings were taken.

A. Voltage of 603-volt supply to welder dropped 21.9%. (Note that drop as read on indicating voltmeter was only 4.5%.)

B. Current of 603-volt supply to welder was 4800 amps. (Root mean square during weld.)

C. Current in weld was 90,600 amps. (Root mean square during weld.)

D. Voltage of 13.8 kv. bus in substation E at point of feed to welder power transformer dropped 9.7%.

E. Voltage of the 13.8 kv. tie-line to substation *F* dropped 4.4%. This indicates the drop on the central substation bus as this tie line is energized from a 13.8 kv. feeder different from the one supplying the welder. Note that the capacity of the supply to the central substation bus was $^1/_2$ normal at the time these tests were made.

F. Voltage of the 575-volt shop lines in Plant *E* supplied through Y-delta connected transformer bank substation *E* dropped 6.7%.

All readings but the last were definitely taken from the same phase. It should be noted that the general plant voltage drop of 4.4% (in one phase) observed at (*E*) is reduced $^1/_2$ when the central substation bus is operating with full capacity supply, and is probably further reduced by the time it reaches the 575-volt distribution system by the balancing effect of synchronous and induction motor shop load.

Company E—Installation

In this plant like in many others where acquisition of new equipment and general expansion have been gradual, the majority of the welding equipment is widely scattered all over the plant. Furthermore, because of the nature of the plant's business, drastic changes in the location of a large portion of the welding equipment available are quite frequent. When they occur, certain general shifts in power loads and temporary feeds are sometimes made which result in different power supply conditions.

For these reasons to present a general picture of the power feed of all welding equipment used would be both difficult and inconclusive. Accordingly this report is limited to a description of power supply of one group of welders which, because of the time and permanency of their installation, can be treated as an integral unit.

General Description of Equipment

The resistance welding equipment comprising this group consists entirely of spot and seam welders. All but two are of the pedestal stationary type. One is a fully portable welding gun and one a semi-portable type with provision for 30-foot travel. All stationary machines are located within 50 feet of the distribution board.

The kva. capacities of the equipment are shown in Fig. 10. It will be noted that several of the machines have full load capacities of such magnitude that were they to form part of the normal production load unsatisfactory voltage regulation would result with the power supply available. However, the maximum production requirements of these machines are considerably lower, as shown on the "Normal Maximum" line, and rather than increase the power supply installation mechanical provisions are made preventing setting of these machines at a tap higher than the normal maximum for all work except experimental, which is conducted by plant engineers only when this group is inoperative, and with one machine at a time.

Load Conditions

The total maximum load is 1375 kva. This load, however, corresponds to operation with short-circuited secondaries. The actual working loads of these machines run 5% to 15% less, depending on the machine and the material used. Assuming an average of 10%, the actual maximum load becomes 1237.5 kva. Application of this load to the 460-volt bus results in a net drop of 13.6% on this bus which would be excessive from the welding point of view. In addition it produces a 5% drop on the 2300-volt bus which is also considered undesirable.

However, the application of maximum load presupposes two facts—(1) that every machine is operated

at its maximum setting. (2) That every machine should fire at the same time. As the machines are operated most of the time at set-ups averaging 50% capacity, and as the combined duty and welding cycle (time of flow of current to total operating time) is between 5 and 25%, the probable maximum load is considerably smaller.

Prolonged and extensive oscillographic studies of the group failed to reveal load peaks higher than 500 kva. with a highest daily average around 250 kva.

No attempt has been made to measure the kw. or kwh. loads as no evidence of heating of transformers, equipment or feeders has ever been observed.

Power Supply

The power is supplied by two 333 kva., 2300/460-volt single-phase, 3.56% impedance, oil immersed self-cooled transformers connected in parallel. The transformers are installed on an out-door platform adjacent to the floor housing the welding equipment. The 460-volt bus and distribution are thus not over 10 feet from the transformer bank.

The transformer bank is fed from a 2300-volt bus which, in addition to the welding load, also feeds a miscellaneous motor load averaging about 300 kva., 2 phase with a normal maximum 15 minute demand of around 650 kva., 2 phase.

The 2300-volt bus is fed by a 930 kva., 2 phase transformer bank (belonging to the power company) consisting of 4—333 kva., 13,800 to 2300 volt, 1 phase oil immersed self-cooled transformers, star connected.

Distribution System

The 2300/460-volt transformer bank is fed from the 2300-volt bus by 2—250 M-circular mil. stranded copper cables through an automatic oil circuit breaker equipped with instantaneous overload trip normally set at 500 amperes. The circuit breaker thus, besides providing short circuit protection, provides against dangerously high overloads which would result in excessive voltage drop.

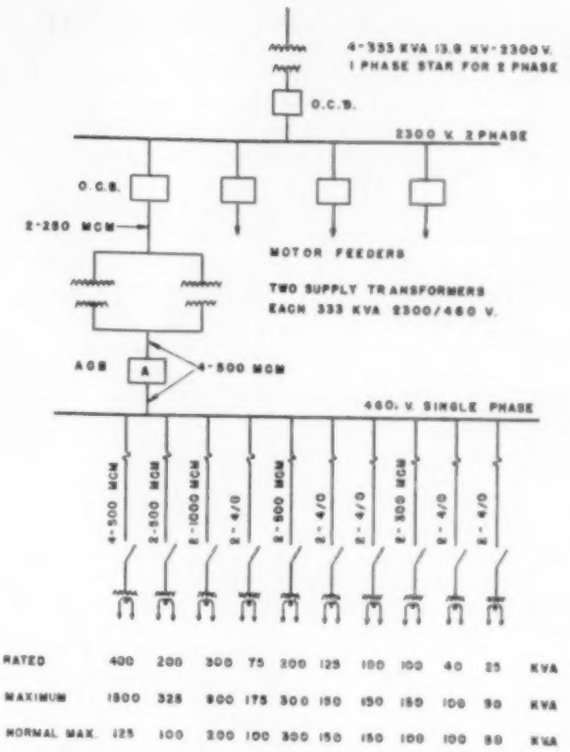
The secondary side of the 2300/460-volt bank is connected by 4—500 M-circular mil. stranded copper cables through an air circuit breaker to a fused distribution board. The individual machines are connected to the distribution board by feeders whose size is based on their length in such fashion that their voltage drop at the normal maximum load shall not exceed 0.25%.

The 460-volt bus is provided with a recording voltmeter and an audible under voltage alarm signal set to operate at a $7\frac{1}{2}$% drop below the normal open circuit voltage.

Conclusion

The extensive voltage regulation studies, extending over a period of several years, appear to indicate that the normal voltage fluctuation on the 460-volt bus is plus or minus 3% of the average operating voltage. Under exceptional operation conditions a drop of −4% has been observed. At the same time the voltage fluctuation of the 2300-volt bus during normal operating conditions has been plus or minus 2% of the average operating voltage.

These voltage conditions appear to be entirely satisfactory both from the plant operating and welding standpoints. For this reason the company has discontinued the use of an automatic instantaneous operation type voltage regulator which was originally part of this installation. The use of the voltage regulator, although it proved to be entirely practical, did not appear to be justifiable in this case as it presented certain problems and the further improvement in the voltage regulation it offered did not appear to be essential.



RATED	400	200	300	75	200	125	100	100	40	25	KVA
MAXIMUM	1800	325	800	175	300	150	150	150	100	90	KVA
NORMAL MAX.	125	100	200	100	300	150	150	100	100	80	KVA

Fig. 10—Schematic Diagram of Welder Supply System, Company E

Company F—Installation

I. *Method of Service by Power Company*

The power company supplies all of the load at the plant through two stepdown transformer banks each rated 1500 kva. One bank supplies all the small loads from a 120/208-volt radial system and the second bank supplies all the large loads and welders in the plant at 240 volts. The transformer banks are supplied from a 13,200-volt circuit, which is fed from two large substation buses. The entire load is metered on the primary side of the transformers and the customer owns the transformers.

II. *Cost to Power Company to Serve Welder Load*

No special equipment or expense was required by the power company to supply the welder loads. Voltage dip was not great enough to cause objectionable light flicker.

III. *Plant Distribution for Welders*

The transformer bank supplying the welders consists of 3—500 kva. transformers connected delta-delta of 4.4 per cent reactance and 1.7 per cent resistance. The welders are in two groups at two widely separated locations.

The first group, of which the largest welder is rated 125 kva., is supplied over a three-phase line consisting of three sets of three 800,000 cm. copper conductors in parallel. Other welders in the group are taken from a three-phase bus about 100 feet long made up of two $\frac{1}{4}$ by 4-inch copper conductors per phase, also supplied from the 800,000-circular-mil. conductors.

The second group, of which the largest welder is 400 kva., is supplied from about 50 feet of three-phase bus made up of four 1/4 by 4-inch copper bars per phase, with a spacing of 1/2 inch between bars. The center lines of the phases are spaced about 6 inches apart.

Welder Feeder Protection

The bus to the second group, which includes the largest welders, is connected directly to the secondaries of the power transformer. The circuit to the other group is supplied through a low voltage air circuit breaker.

Type and Rating of Welders

The largest welders in both groups are spot welders. The first group includes 21 welders having a combined rating of 1300 kva., of which the largest is 125 kva. The second group includes 5 welders having a total rating of 1100 kva. of which the largest is 400 kva.

Voltage Drop Data

The following calculated voltage drops at various points on the distribution system apply to 0.4 power factor loads, which oscillograph records show to be closely approximated:

	Location 1 800-Kva. Load, Per Cent	Location 2 150-Kva. Load, Per Cent
On 13.2-kv. line at the plant	1.5	0.3
On 240-volt bus	5.3	1.0
On 240-volt circuit at welder	8.0	2.0

Equivalent Thermal Heating

The timing on all of the spot welders is between 15 and 20 cycles. The time between welds is about 3 seconds on the larger welder and one second on the smaller group. The equivalent kva. on a heating basis is about 150 kva. for the larger group and was about 275 kva. for the smaller group.

Acknowledgments

The A.I.E.E. Subcommittee on Power Supply for Welding Operations wishes to acknowledge with thanks the assistance given by the following organizations in the preparation of this report: Midland Steel Products Company, Packard Motor Car Company, The Firestone Rubber and Metal Products Company, The Heintz Manufacturing Company, General Electric Company, and Crosley Corporation.

Crusher Repair

By J. L. BEARDEN*

THE pictures are of a cast steel swing jaw from a size 66 in. x 86 in. Traylor Jaw Crusher, manufactured by the Traylor Engineering & Foundry Manufacturing Co., Allentown, Pa. This crusher and two others the same size, are the largest ever manufactured, costing $67,000.00 when new.

*Engineer, Compressed Industrial Gases, Inc., Chicago Ill.

Rion Crushed Stone Corp., Rion, S. C., is the owner of this particular crusher and it is used for crushing waste Blue Granite stone from a dimension stone quarry. Stone as large as 4 ft. square is crushed with a total crushing capacity of 800 ton an hour through a 9-in. opening.

100-Ton Crane Moved Jaw Into Welding Position

Huge Cast Steel Swing Crusher Jaw Repaired on the Job in South Carolina

The swing jaw is of hollow cast-steel construction with vertical and horizontal ribs and body of 5-in. steel. The face of the swing jaw is 7 ft. x 16 ft., to which the jaw plates are bolted, and the body is 3 ft. 6 in. thick at the widest point, weight being 80,000 lb.

While in operation a piece of the lower section of the swing jaw, weighing approximately 25,000 lb., broke entirely off. Since the failure of this crusher halted the operation of the entire quarry, it was important that it be put back to service in the shortest possible time.

Upon investigation it was found that the earliest possible delivery of a new swing jaw would be 90 days, and then only if the first casting were free of slag inclusion. Cost, delivered in Winnsboro, S. C., to be $12,900.00.

Because of the time required to obtain a new swing jaw and unfilled orders on hand, it was decided to arc weld the broken jaw.

The welds were prepared by oxyacetylene cutting. Vees being made from one side, only, so that the welds could be made from the outside. The cuts were then cleaned by sand-blasting to remove all slag. 18–8 Stainless Steel electrodes, $^3/_{16}$ in. were used for the first beads in the bottom of the welds to increase the ductility.

Protected arc, $^3/_{16}$-in. electrode, was then used to complete the welds. The back step method was used on all welds, with each bead being peened with an air-hammer and thoroughly cleaned before the next bead was laid.

At the points where the three vertical ribs joined the broken casting, the ribs were cut off $3^1/_2$ in. to allow for steel plates $3^1/_2$ in. thick between the ribs and the broken casting, as the broken casting was very poor due to slag inclusion. These plates were cut so that all the welds would be laid on good metal in the broken casting, and then welded to the ribs. After all the welds were completed on the original swing jaw, a piece of steel 7 ft. x 16 ft. x $2^1/_2$ in. was fillet welded on the face of the jaw for reinforcement.

A wood and sheet metal building was built to protect the job and men from the weather. This building was so designed that it could be lifted by the crane when a change of position in the jaw was necessary. A 100-ton railroad type crane was used to position the jaw so that the welds could be made in flat position. The welding was done by four welders who worked two on day shift and two on night shift.

The crusher was put back in service 53 days after failure with a total cost of $3778.53. The saving, as compared to a new jaw, being $9121.47 added to five weeks operating time that would have been lost if a new jaw had been purchased.

Used in the welding was 100 lb. $^3/_{16}$-in. 18–8 Stainless Steel and 3600 lb. $^3/_{16}$ in. of the protected arc electrodes.

Below is an itemized list of cost as set up by the Rion Crushed Stone Corp.:

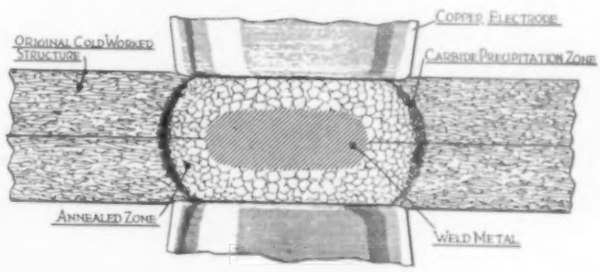
Supervision	$ 250.00
Skilled Labor	1044.06
Common Labor	479.02
Welding Rods	338.74
Oxygen & Acetylene	272.58
Steel Plates	584.13
Compressor (day)	200.00
Compressor (night)	160.00
House	125.00
Electric Power	180.00
Miscellaneous	145.00
	$3788.53

Mr. H. B. St. Lawrence, President, and Mr. S. E. Jennette, Secretary and Treasurer, of the Rion Crushed Stone Corp. gave the author the information contained in this article.

Improper Spot Weld

By J. W. MEADOWCROFT*

In the opposite column there is shown a schematic drawing of an improperly made resistance weld in cold-rolled stainless steel "18–8." (Weld shows harmful carbide precipitation.) This shows how modern methods of examination of welds under the microscope give exact information as to the properties of the weld, the size of the weld and the presence or absence of desirable



constituents. Such information makes possible accurately controlled welding such as in the "Shotweld" process. Old methods consisted of simply tearing the weld apart in a vise.

* Assistant Supt., E. G. Budd Manufacturing Co.

Welding Society ACTIVITIES — Related Events

RESISTANCE WELDING PRIZE PAPERS

In the last issue of THE WELDING JOURNAL complete rules and regulations were given for the Resistance Welding Prize Contest. This is an unusual opportunity to win a substantial prize for a paper dealing with resistance welding. Several important members have indicated their intentions of presenting papers. All members of the Society are urged to give this matter their careful consideration.

HIGH SPOTS ANNUAL MEETING TECHNICAL PROGRAM, CLEVELAND, OCT. 20-26, 1940

The Technical Program will open on Monday, October 21st. There will be the award of the Samuel Wylie Miller Medal and the Lincoln Gold Medal, which is to be supplemented this year by prize awards for the best Resistance Welding papers. To save time a keynote speaker has been dispensed with.

Altogether there are 15 technical sessions involving more than 55 papers. Acceptances have already been received from 45 of the prospective authors. Simultaneous sessions have been arranged on each day except the Opening Session. Thursday afternoon will be free for visitation to the National Metal Exposition and for committee meetings. On Monday evening there is to be an Industrial Research Conference, on Tuesday a Fundamental Research Conference.

The annual business meeting will be held as last year on Friday morning. An inspection trip has been provided for on Friday afternoon. A wide range of subjects will be covered including the applications of welding and allied processes in structural work, steel mill applications, machinery, pipe, ship, railroad, aircraft, alloy steels and several others. Special sessions will be devoted to results of Fundamental Research, Industrial Research, and Resistance Welding applications.

In addition to the technical program there will be the President's Reception on the Sunday preceding the meeting, special provision for ladies entertainment and an Annual Banquet on Thursday evening at which there will be no speakers.

Indications are that the Exposition and Meeting will far surpass the record-breaking event held in Chicago last year.

WELDING HANDBOOK COMMITTEE

In connection with the second edition of the Welding Handbook, the Committee consisting of C. A. Adams, H. C. Boardman, W. F. Hess, C. W. Obert, W. Spraragen, Editor, reported that progress was being made. The Committee told the Board of Directors that a preliminary outline of chapters had been prepared but that this was not in final shape as yet. The Committee proposes to improve the new Handbook through a somewhat different approach in the preparation of the material. Instead of individual authors, chapters will be prepared by specially selected committees. The first part of the new volume will be devoted to fundamental considerations such as physics and metallurgy of welding in general, and these chapters will be followed by complete treatment in a fundamental way, of all the major and allied processes of welding and related applications.

The next group of chapters will deal with the welding of the common metals and alloys and then a series of chapters will be devoted to training, inspection and safety. There will also be some space devoted to design considerations but the exact form of this group of chapters has not been decided upon. The volume will close, like the first edition, with several chapters devoted to applications of welding.

No date was set for the issuance of the Handbook. It is expected that this will take place late in 1941 or early in 1942.

NEW BULLETINS

The following new Bulletins are now available at 25¢ each.

Standard Methods for Mechanical Testing of Welds
Definitions of Welding Terms and Master Chart of Welding Processes
Tentative Rules for Field Welding of Storage Tanks

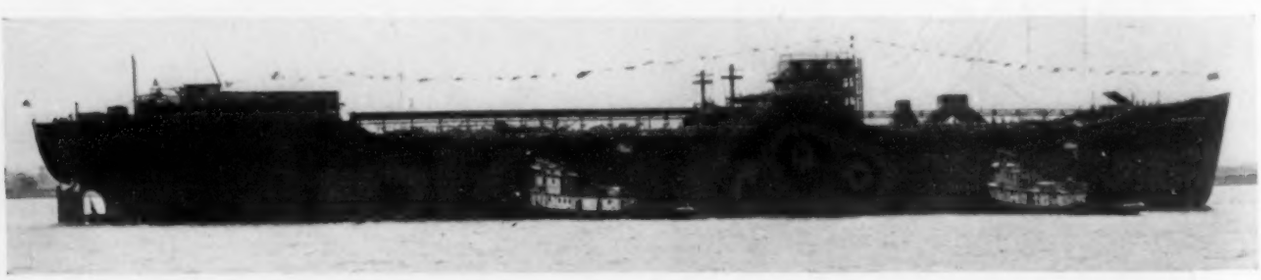
Copies may be ordered from the AMERICAN WELDING SOCIETY, 33 West 39th Street, New York.

WELDED TANKER

Chester, Pa., May 11th—The Atlantic Refining Company's new 19,405-ton tanker, the S.S. Robert C. Tuttle, was launched here today at the yards of the Sun Shipbuilding and Dry Dock Company. The new vessel was christened by Mrs. Robert C. Tuttle, wife of the vice-president of The Atlantic Refining Company for whom the latest addition to the Atlantic fleet is named.

The S.S. Robert C. Tuttle is a turbo-electric tanker of all-welded construction, and is similar in design to her three sister ships of the Atlantic fleet—the S.S. J. W. Van Dyke, the S.S. Robert H. Colley and the S.S. E. J. Henry—all commissioned within the past three years. The new oil carrier will be the eighteenth electrically propelled ship designed by Atlantic engineers, and her addition to the fleet will give Atlantic more electrically propelled vessels than any other company in the world.

Over-all length of the S.S. Robert C. Tuttle is 544 feet. Capacity is the equivalent of 156,000 barrels, or 6,552,000 gallons. The turbo-electric engines are designed to develop 5000 horsepower, providing a sea speed of 13.25 knots. The steam generating system is of the high-pressure, high-temperature type, operating at 625 pounds pressure and at a steam temperature of 920° F.



The S.S. Robert C. Tuttle, The Atlantic Refining Company's New 19,405-Ton Tanker, in the Delaware River Immediately After Her Launching at the Sun Shipyards, Chester, Pa., May 11, 1940

FIFTEEN YEARS PROGRESS BY RESISTANCE WELDING

COST REDUCED

62.7%

Showing a typical example—a rear axle housing. This saving in spite of an hourly wage increase from 72.3 to 92.9 cents.

MAKING POSSIBLE LOWER AUTO PRICES

"More for your money" has been the trend of the automobile industry for the past fifteen years. Contributing greatly has been the ever increasing application of resistance welding, making possible light, strong housings, bodies, fenders and other parts at lower costs. Typical in rear axle housings are price reductions up to 62.7% from 1925 to 1940 models. Due to welding, present day axle housing design is possible, greatly reducing weight, permitting savings in material and lowering production costs.

Since resistance welding has made these same savings in various industries, replacing more expensive methods, perhaps it can do the same for you. Any of the member companies listed here will be glad to consult with you on your particular problem.

RESISTANCE WELDER MANUFACTURER'S ASSOCIATION

505 Arch Street Philadelphia, Pa.

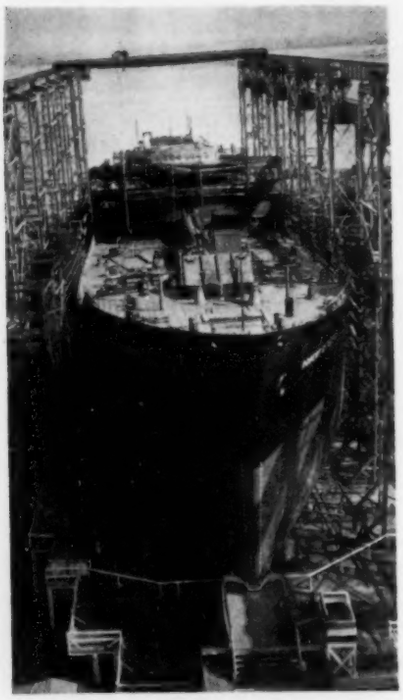
RESISTANCE WELDER MANUFACTURERS ASSOCIATION • RWMA

MEMBER COMPANIES

Acme Electric Welder Company, Los Angeles
American Electric Fusion Corporation, Chicago
Eisler Engineering Company, Newark, N. J.
Expert Welding Machine Company, Detroit
Federal Machine and Welder Company, Warren, Ohio
Multi-Hydromatic Welding and Manufacturing Co., Detroit
National Electric Welding Machines Co., Bay City, Mich.
Progressive Welder Company, Detroit
Swift Electric Welder Company, Detroit
Taylor-Hall Welding Corporation, Worcester, Mass.
Taylor-Winfield Corporation, Warren, Ohio
Thomson-Gibb Electric Welding Co., Lynn, Mass.
Welding Machines Mfg. Company, Detroit

ASSOCIATE MEMBER COMPANIES

P. R. Mallory and Co., Indianapolis
S-M-S Corporation, Detroit
Electroloy, Inc., New York
Welding Sales and Engineering Co., Detroit



The S.S. Robert C. Tuttle on the Ways at the Sun Shipyards, Chester, Pa., Just Prior to Her Launching

The newest addition to the Atlantic fleet will be placed in service in July on the run between Philadelphia and Texas Gulf ports.

FIRST ANNUAL PACIFIC COAST LIQUEFIED PETROLEUM GAS EXPOSITION

With the use of butane-propane mixtures for cutting and heat-treatment assuming an ever-widening rôle, the announcement that the Pacific Coast Liquefied Petroleum Gas Exposition will be held in the Municipal Auditorium, Santa Barbara, California, June 27th and 28th, will be received with wide interest. A number of the displays will feature cutting and butane driven arc machines.

Arrangements for the Exposition are being handled by John H. Kunkel, Secretary, Pacific Coast Section, Liquefied Petroleum Gas Association, 1625 South Alameda Street, Los Angeles, California, and those desiring full information are requested to communicate with him. No admission fees will be charged and all interested parties are cordially invited to attend.

THE ENGINEERING FOUNDATION REPORTS TWENTY-FIVE YEARS OF SERVICE

The Engineering Foundation was established in 1914 "for the furtherance of research in science and engineering, or for the advancement in any other manner of the profession of engineering and the good of mankind." Its immediate objective is the furtherance of researches directed toward solutions of problems of benefit to the profession and the public, of technological and human interest, in which engineering methods and knowledge may be utilized.

The current year completes twenty-five years of activity. The Foundation has issued a booklet in which an attempt has been made to evaluate, at least partially, the significance of some of the more important research projects that have been assisted by grants of funds from the income of the Foundation. This review is evidence of the importance of the Foundation's work in initiating, organizing, administering and assisting in the financial support of worth while investigations and research projects.

Toward the achievement of its objectives The Engineering Foundation aids in originating, organizing, financing and following through, technical and other projects of broad interest which are within its scope. It refrains from direct management and has no laboratories nor staff nor other facilities for the conduct of research, but cooperates with technical and scientific organizations, industries, trade associations, educational institutions and Governmental bureaus.

During the twenty-five years of service seventy-three researches and projects have been assisted by funds appropriated from the income of the investments of the Foundation to an amount of over $400,000. Cash contributions for certain projects have passed through the accounts of the Foundation to an amount of nearly $500,000. In addition other large sums have been contributed by the four Founder Societies, and by individuals, corporations and industry. Likewise the use of facilities made available by educational institutions and laboratories, and the expert supervision freely donated by many individuals have been of great value, but a large part of such service cannot be expressed in an equivalent money value. Of special interest to our readers is the Welding Research. This current project was undertaken "to assemble, digest, and publish in readily accessible form information available in the world's literature. . . . to conduct researches in our universities on special welding problems needing solution . . . to conduct and stimulate research needed on broad problems in the welding field . . . . and to correlate existing and future programs of welding research." The program is being carried out largely through committees devoted to Literature, Fundamental Research and Industrial Research. Under the direction of the committees, the activities of many widely scattered groups of research workers are integrated.

RECENT ADVANCES IN ENGINEERING AND RESEARCH

Machines fast enough to measure lightning and others so sensitive that they anticipate changes in speeds before they have time to take place were cited as proof that "the electrical industry will continue to grow under the stimulation and impetus of new scientific discoveries and advances." M. W. Smith, vice-president in charge of engineering for the Westinghouse Electric & Manufacturing Company, recently described these and a number of other recent electrical developments during an address before the New York Railroad Club.

The engineering executive also disclosed that a new welding procedure is in a state of commercial development which will make it possible to weld structural steel assemblies at a much higher rate than at present. "It is now possible," he said, "to weld together sections of steel as thick as one inch in a single pass, at a speed of 30 inches a minute, and obtain uniform and sound welds under laboratory-controlled conditions."

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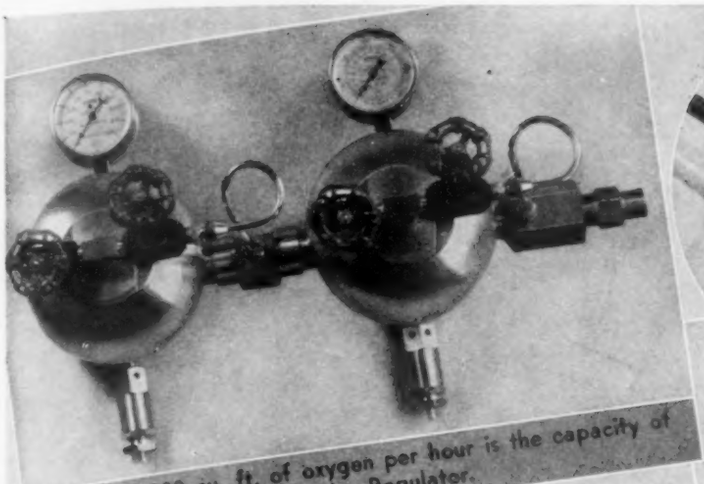
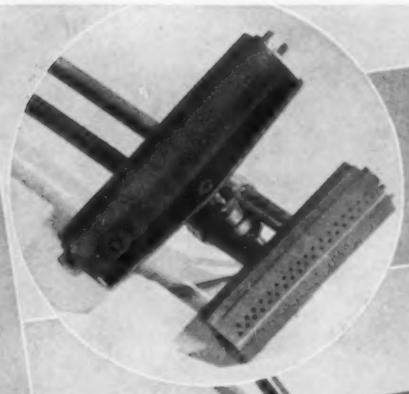


Over 100,000 cu. ft. of oxygen per hour is the capacity of this Duplex Regulator.



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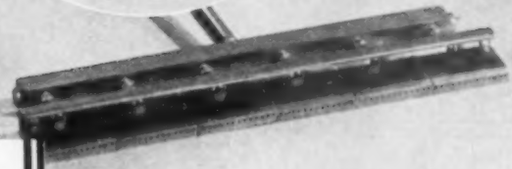

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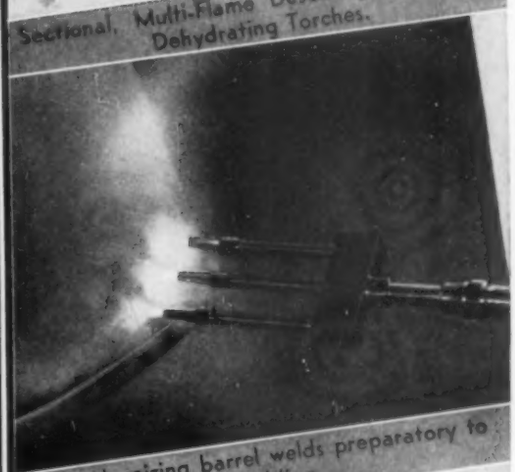
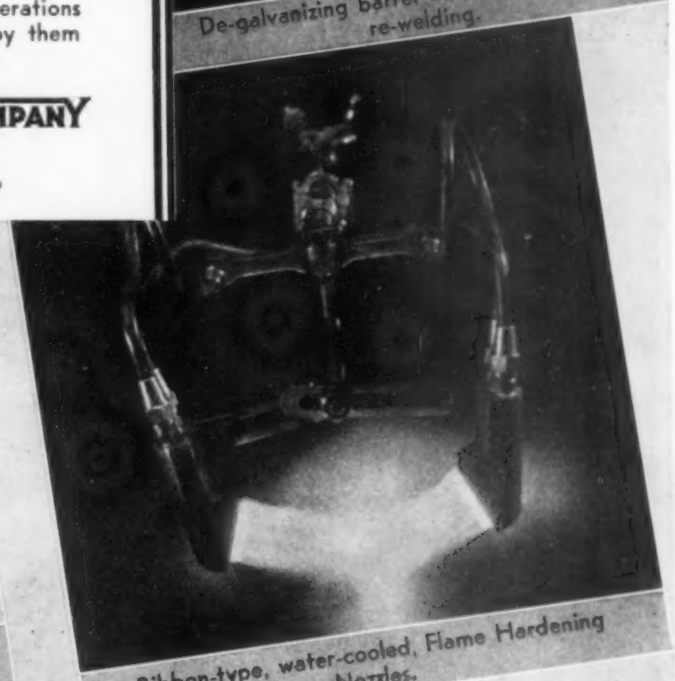


De-galvanizing barrel welds preparatory to re-welding.



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FIELDS OF INTEREST TO A. W. S. MEMBERS

The Meetings and Papers Committee recently sent out a questionnaire to the entire membership of the SOCIETY asking them to indicate major preference and general interest in specific subjects. This questionnaire also provided an opportunity for the members to submit comments and to indicate whether or not they would be willing to prepare a paper for Section meetings, National meetings and the JOURNAL. The results of the questionnaire received to date are reproduced below.

Fields of Interest	Votes
Maintenance and Repair	399
Construction	375
Production and Manufacture	506
Research, Fundamental	377
Research, Industrial	435
Design Methods and Data	554
Economics	251
Metallurgy	527
Development Work	287
Educational	232
Operation	200
Type of Papers	
Apparatus and Equipment	360
Techniques, Procedures	686
Test Results	421
Filler Metal	275
Theory	384
Specification and Codes	411
Inspection, Training	344
Acceptance Requirements	193
Safety	203
News	181
Pictoral Reviews	184
Metals	
Low Carbon Steel	710
Low Alloy Steel	587
High Alloy Steel	444
High Carbon Steel	355
Cast Iron	273
Cast Steel	311
Copper, Brasses and Bronzes	348
Aluminum and its Alloys	307
Nickel and Its Alloys	367
Other Non-Ferrous Metals	234
Welding Processes	
Arc, Manual	879
Arc, Machine	457
Gas	445
Resistance	304
Resistance Welding Controls	178
Thermit	90
Cutting Hand	352
Cutting Machine	367
Atomic Hydrogen	190
Applications	
Aircraft	221
Automotive	224
Shipbuilding and Repair	371
Railroad and Railway, Shops	222
Railroad and Railway, M. of W.	140
Pipe Lines and Piping	431
Pressure Vessels	538
Welding Shop and Maintenance Problems	421
Tanks	423
Structural Steel and Bridges	441
Light Gauge Production Work	262
Jigs and Fixtures	326
Machinery	315
Hard Facing and Surfacing	386
Steel Mills	156
Metal Spraying	199
Low Temperature Brazing	187
Bronze Welding	251
Flame Hardening and Softening	291
Oil Industry	252
Deseaming, Descaling, Gouging and Flame Cleaning	216

A DICTIONARY OF METALS AND THEIR ALLOYS

Edited by F. J. Camm, 1940, price $3.00. Containing descriptions of the metals, their composition and characteristics, with special sections on plating, polishing, hardening and tempering, metal spraying, rust-proofing, chemical coloring, and useful tables. This is the first alphabetically arranged Dictionary of Metals and Their Alloys yet published. With an ever-growing list of new alloys having special properties and intended for particular uses, it is important that engineers should have at hand an easily consulted book which gives the analysis and characteristics of all of the known metals. Chemical Publishing Co., Inc., 148 N. Lafayette Street, New York, N. Y.

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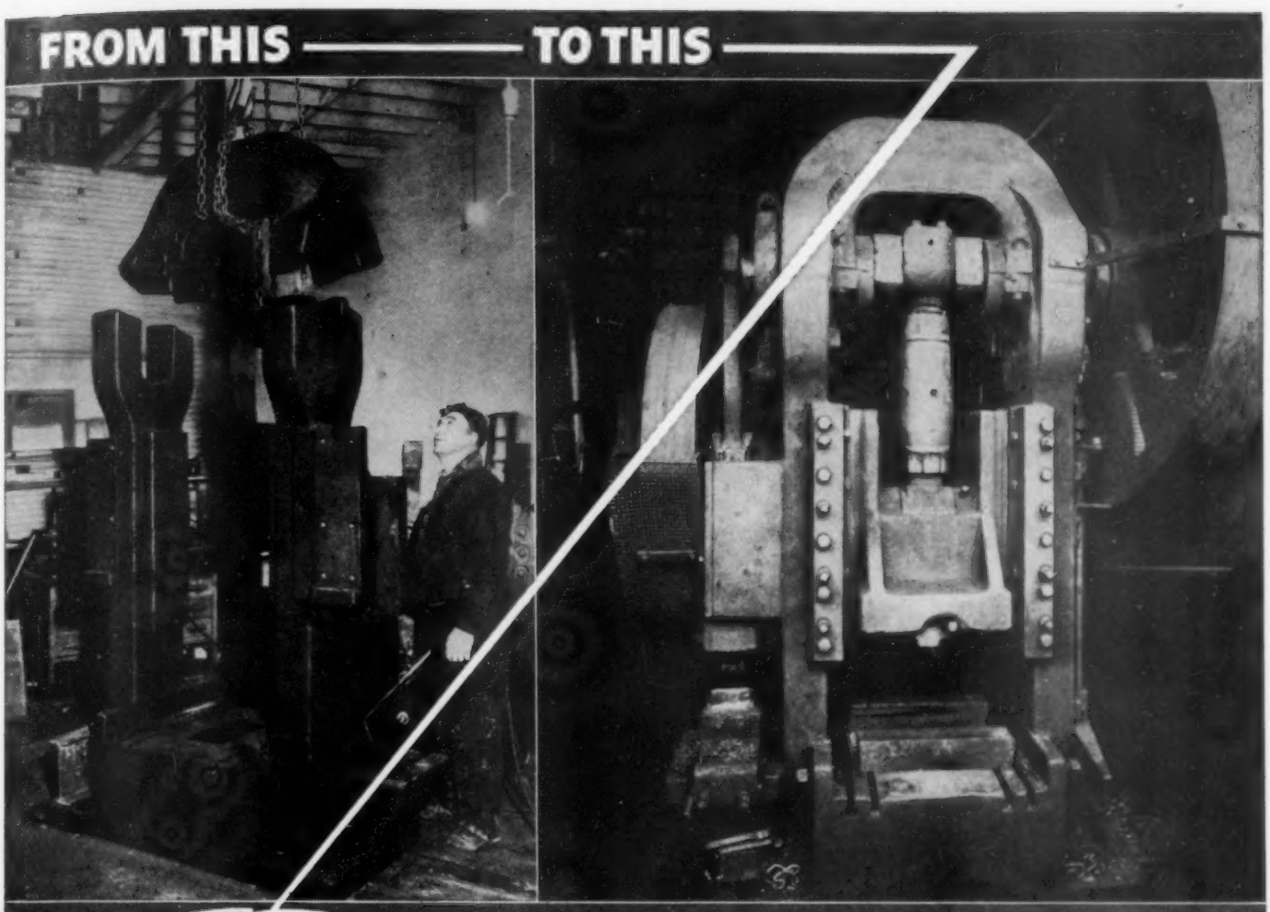

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The job consumed 160 pounds of filler rod and 1,600 feet of both oxygen and acetylene. Chipping, preheating with natural gas and compressed air and other preparation required 35 hours; welding, 11 hours. The result was a strong sound weld and a happy production manager, for the downtime loss was only a fraction of what he expected.

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WELDING ENGINEERING CONFERENCE

The Ohio State University held a very successful conference—the 9th—on April 16th, 17th and 18th. Unlike other conferences, a fee of $5.00 was charged at the time of registration. This included the cost of the dinner. The lectures were held in the Social Administration Building on the campus. The program was devoted entirely to lectures and discussions by engineers prominent in welding and by members of the staff. Some fifty people attended the conference. There follows a program of the Conference.

Tuesday, April 16th

10:45 A.M. Address of Welcome, J. L. Morrill, Vice President, The Ohio State University.

11:00 A.M. to 1:00 P.M. "Combined Stress Analysis," Samuel B. Folk, Associate Professor of Mechanics, The Ohio State University.

2:30 P.M. to 4:00 P.M. "Welding Symbols," J. R. Stitt, Assistant Professor of Welding Engineering, The Ohio State University.

4:00 P.M. to 5:00 P.M. The "Contraction Method" used to straighten bent steel members, Joseph Holt, Washington State, Department of Highways.

Wednesday, April 17th

Morning Session—Chairman, J. R. Stitt

9:00 A.M. to 11:00 A.M. "The Properties of Weld Metal," Leon C. Bibber, Welding Engineer, Carnegie-Illinois Steel Corporation.

11:00 A.M. to 1:00 P.M. "Production Welding," Robert M. Wallace, Welding Engineer, The Griscom Russell Company.

Afternoon Session—Chairman, Clyde T. Morris, Professor, Civil Engineering Department

2:30 P.M. to 4:30 P.M. "Welded Joints as Applied to Structures, Storage Tanks, etc.," Leon C. Bibber, Welding Engineer, Carnegie-Illinois Steel Corporation.

6:30 P.M. Dinner—Fort Hayes Hotel. Toastmaster, Charles E. MacQuigg, Dean College of Engineering, The Ohio State University.

Talk: "Crystals and Their Properties," By William J. McCaughey, Professor of Mineralogy, The Ohio State University.

Kodachrome Views of the West, By George N. Moffat, Assistant Professor of Mechanical Engineering, The Ohio State University.

Thursday, April 18th

Morning Session—Chairman, Carl A. Norman, Professor of Machine Design, Ohio State University

9:00 A.M. to 11:00 A.M. "Welded Joints as Applied to Machinery, Pressure Vessels, Pipe, etc.," Leon C. Bibber, Welding Engineer, Carnegie-Illinois Steel Corporation.

11:00 A.M. to 1:00 P.M. "Production Welding," C. Perry Streithof, Structural Division Engineer, Dravo Corporation.

2:30 P.M. to 4:30 P.M. "Possibilities in Analysis in Three Dimensional Stress by the Use of Models," Percy W. Ott, Professor of Mechanics, The Ohio State University.

A. S. M. E. THREE-CITY SUMMER MEETING

For the first time in the history of The American Society of Mechanical Engineers, the 1940 Semi-Annual Meeting will be held in three cities at the same time. With simultaneous meetings taking place in Milwaukee, Wis., at the Hotel Pfister, June 17th–20th; in Ann Arbor, Mich., at the University of Michigan, June 20th–21st; and in Asbury Park, N. J., at the Berkeley-Carteret Hotel, June 19th–22nd; more members will be afforded an opportunity to attend one group of technical sessions and to take part in the attendant social functions, according to Erik Oberg, chairman of the A. S. M. E. Meetings and Program Committee.

Featured at the main meeting in Milwaukee will be 13 technical sessions with 30 papers covering hydraulics, steam power, education and training, management, fuels, machine-shop practice, process industries, and railroads, several plant trips, luncheons, business meeting, and a banquet. The meeting at Ann Arbor,

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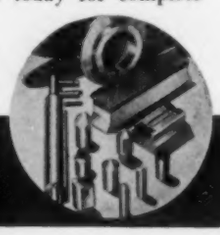

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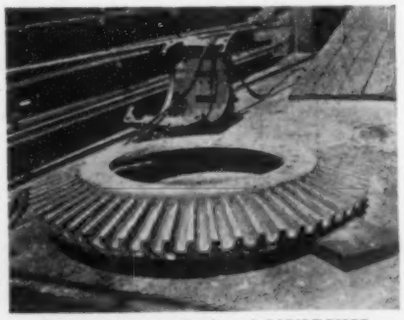

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under the sponsorship of the Society's Applied Mechanics Division, will present four technical sessions, devoted to elasticity, dynamics, fluid mechanics, and thermodynamics, with 13 papers by some of the outstanding engineering theorists of the country. Besides an exhibit of Diesel engines and accessories, the A. S. M. E. Oil and Gas Power Division's meeting in Asbury Park will include six sessions with 12 technical papers on the subjects of Diesel-engine fuels, shaft couplings, marine Diesels, engine design, operation, and maintenance.

OUTPUT OF WELDING WIRE AT NEW PEAK*

Reflecting Wider Use, Output Highest by 18%

Production of steel welding wire in 1939 rose to the record-breaking total of 183,436,000 pounds, according to information received by the American Iron and Steel Institute.

Welding wire output in 1939 represented an increase of 56 per cent over the 1938 figure of 117,395,000 pounds and was 18 per cent greater than production in 1937 of 155,310,000 pounds, the highest total previously recorded.

Between 1932 and 1939 the production of steel welding wire rose 760 per cent, more than double the increase in total amount of steel produced during the period.

Reflecting the more extensive uses of welding processes, particularly by manufacturers of products in which steel is used, more than 5 pounds of welding wire were produced per net ton of finished steel last year, compared with 2.6 tons in 1932.

The following table shows the actual and relative increase in welding wire production over the past eight years.

	Production of Welding Wire (Pounds)	Per Cent of 1932 Production Welding Wire	Per Cent of 1932 Production Steel Ingots
1932.....	24,150,000	100	100
1933.....	49,450,000	205	170
1934.....	72,100,000	299	193
1935.....	97,750,000	405	252
1936.....	140,300,000	581	353
1937.....	155,310,000	643	374
1938.....	117,395,000	486	210
1939.....	183,436,000	760	346

* Taken from May 1940 *Steel Facts*.

BOTTOM OF STEEL CASTING REPAIRED

When the bottom of a steel casting, a part of a hydraulic press from a rubber mill, became so porous that it had to be replaced, arc welding came to the rescue.

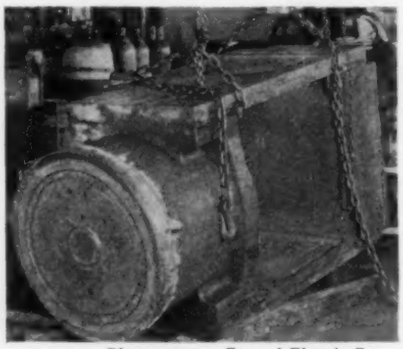


Photo courtesy General Electric Co.

The bottom was cut out by an acetylene torch and replaced by a $2^1/_4$-inch steel plate, arc welded into place. The job was done at a considerable saving by the Menna Welding Company, Toledo.

COMBUSTION OFFICERS

At the annual organization meeting of Combustion Engineering Company, Inc., 200 Madison Avenue, New York, manufacturers of steam generating, fuel burning and related equipment, Joseph V. Santry was elected President to succeed Frederic A. Schaff who was elected Vice-Chairman of the Board. George L. Bourne was re-elected Chairman of the Board. Mr. Bourne is also Chairman of the company's parent organization, The Superheater Company, of which Mr. Schaff is President.

Robert M. Gates, who has been Vice-President in Charge of Sales since 1933, resigned to accept the presidency of The Air Preheater Corporation, 60 East 42nd Street, New York, an affiliated company of The Superheater Company.

Mr. Santry, who has been Executive Vice-President since 1933, became identified with Combustion Engineering shortly after its organization in 1914 and was elected a Vice-President in 1918. He attended Massachusetts Institute of Technology and was first employed by the Boston Elevated Railway Company, of which company he subsequently became Assistant to the Superintendent of Power Stations. Later he organized and became President of the Schumaker-Santry Company of Boston, representatives of Combustion Engineering and other prominent manufacturers of power plant equipment in the New England territory. He is widely known throughout the power industry and is a member of the American Society of Mechanical Engineers and the Engineers' Clubs of New York and Boston.

Martens H. Isenberg, who has been Vice-President in Charge of Production, was elected Executive Vice-President to succeed Mr. Santry.

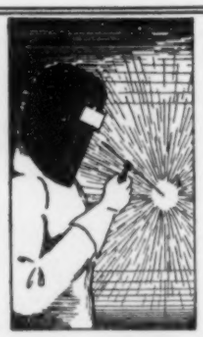
Albert C. Weigel, formerly Assistant to the President, was elected a Vice-President, and the following were re-elected Vice-Presidents: Harold H. Berry, John Van Brunt, F. H. Rosencrants, Charles H. True, John S. Skelly.

Other officers re-elected are: Harold H. Berry, Treasurer, George D. Ellis, Secretary and Controller.

The following re-appointments were made: I. B. Swigart, Assistant Secretary and Assistant Treasurer, Thomas F. Morris, Assistant Secretary. Frank R. Fitzpatrick was appointed Assistant to the Vice-Chairman.

INDUSTRIAL CONTROL STANDARD

The National Electrical Manufacturers' Association announces the release of a new Industrial Control Standard superseding the edition of August 1937. The new publication contains general standards and definitions applying to resistors, contactors, brakes, auto-transformers and reactors, a-c and d-c controllers; machine



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tool, synchronous motor, printing press and mine hoist control; magnetic control for steel mill auxiliaries, overhead traveling and floor operated cranes; terminal markings and guides to specifications for building equipment control apparatus. Copy of the Standard may be obtained for $1.00 by writing to the National Electrical Manufacturers Association, 155 East 44th Street, New York, N. Y.

FEDERAL WORKS MANAGER

Frank J. Schuman has been appointed to the position of Works Manager of The Federal Machine and Welder Company of Warren, Ohio. Mr. Schuman is a graduate of Lehigh University in mechanical engineering and is well qualified for his new duties, having had an excellent experience in industrial engineering, manufacturing and administrative functions.

Prior to joining the personnel of The Federal Machine and Welder Company, Mr. Schuman was associated with The Standard Tube Company of Detroit as Works Manager and with the S. R. Dresser Mfg. Company of Bradford, Pa., in the capacity of Plant Superintendent.

Frank J. Shumann

LINCOLN PRIZE CONTEST

Analysis of the awards and divisions of participation in the Program brings to light a significant fact:

. . . . that while the Program is for the entire industrial field, it is actually 46 individual award programs. Each of the 46 divisions, which together embrace every field of industry, has 4 awards of its own and is automatically eligible for certain other awards—4 in the particular group (or "Classification") of 12 in which it falls, 3 in the Main Award group or, receiving no other award, 223 in the Honorable Mention group.

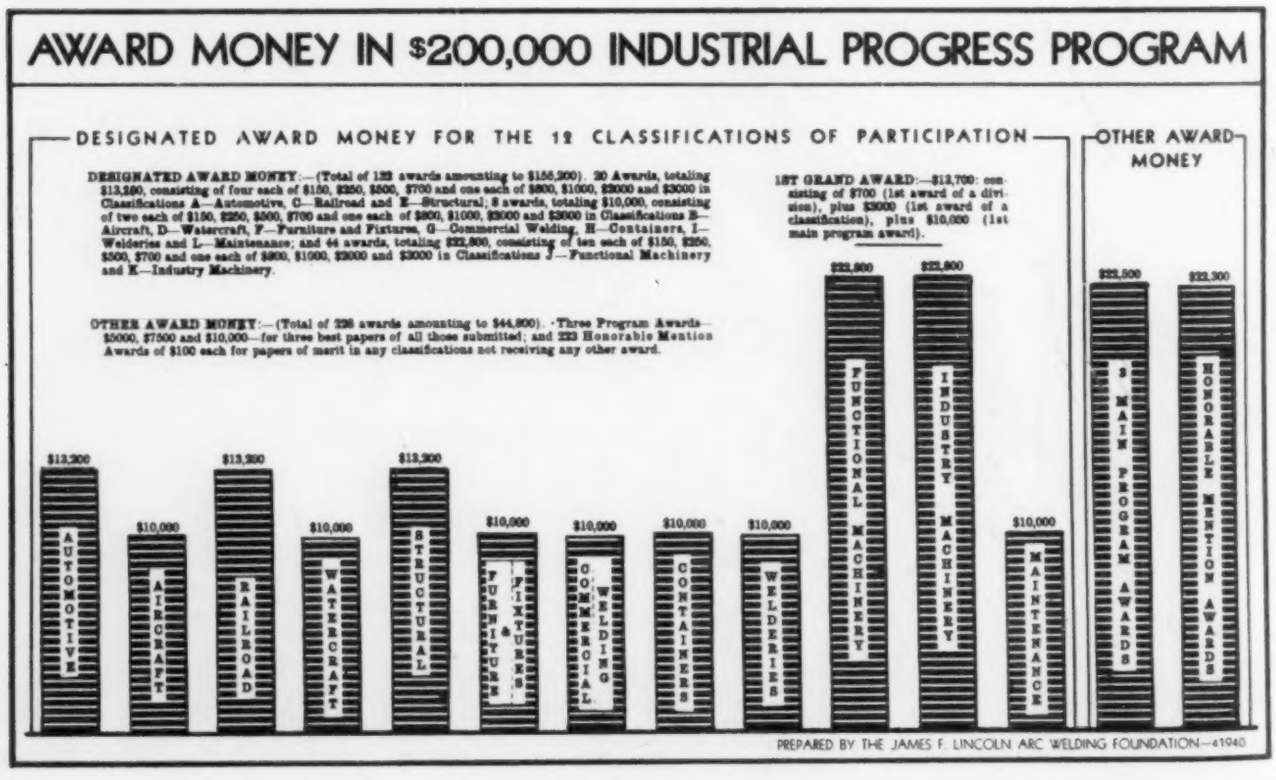
As a typical example from the 46 divisions, take Program Division J-1, which is "Metal Cutting" in the Functional Machinery classification. Four awards—one each of $150, $250, $500 and $700—are definitely designated for "Metal Cutting Machinery." Papers on this subject are also eligible for four other awards—one each of $800, $1000, $2000 and $3000. These are the Classification awards for the best papers of the Functional Machinery group which includes Metal Cutting machines. Then, there are the 3 Main Program Awards—one each of $5000, $7500 and $10,000—for which papers on "Metal Cutting" machines are just as eligible as those on any other subject. These three awards are for the three best papers of the entire Program. Finally, there are 223 other awards—each of $100—for which papers on "Metal Cutting" machines, receiving no other award, are eligible.

Supposing a paper on our typical subject ("Metal Cutting Machines"), should be judged best of all in the entire Program. It would receive $700 (1st award in its division) $300 (1st award in its classification) and $10,000 (1st Main Award of the Program). These added together constitute the 1st Grand Award—$13,700.

The same analysis carried out in the two preceding paragraphs can be made for any of the 46 divisions.

To show the awards in the 12 Main Classifications, which collectively embrace the 46 divisions of participation, the Foundation has prepared the accompanying graphic chart.

The awards of the Progress Program are for reports describing advances and improvements made between now and June 1, 1942, by fabrication, construction, welding service and maintenance. The product or structure may have arc welding actually applied to it within the period or it may simply be designed, or re-designed, within the period to utilize arc welding. In either case, the report is to include a design and description bringing out advances and improvements.


AWARD MONEY IN $200,000 INDUSTRIAL PROGRESS PROGRAM
DESIGNATED AWARD MONEY FOR THE 12 CLASSIFICATIONS OF PARTICIPATION
OTHER AWARD MONEY
DESIGNATED AWARD MONEY:—(Total of 132 awards amounting to $156,200). 30 Awards, totaling $13,200, consisting of four each of $150, $250, $500, $700 and one each of $800, $1000, $2000 and $3000 in Classifications A—Automotive, C—Railroad and E—Structural; 8 awards, totaling $10,000, consisting of two each of $150, $250, $500, $700 and one each of $800, $1000, $2000 and $3000 in Classifications B—Aircraft, D—Watercraft, F—Furniture and Fixtures, G—Commercial Welding, H—Containers, I—Welderies and L—Maintenance; and 44 awards, totaling $32,800, consisting of ten each of $150, $250, $500, $700 and one each of $800, $1000, $2000 and $3000 in Classifications J—Functional Machinery and K—Industry Machinery.
OTHER AWARD MONEY:—(Total of 226 awards amounting to $44,800). Three Program Awards—$5000, $7500 and $10,000—for three best papers of all those submitted; and 223 Honorable Mention Awards of $100 each for papers of merit in any classifications not receiving any other award.
1ST GRAND AWARD:—$13,700: consisting of $700 (1st award of a division), plus $3000 (1st award of a classification), plus $10,000 (1st main program award).
$13,200
AUTOMOTIVE
$10,000
AIRCRAFT
$13,200
RAILROAD
$10,000
WATERCRAFT
$13,200
STRUCTURAL
$10,000
FURNITURE & FIXTURES
$10,000
COMMERCIAL WELDING
$10,000
CONTAINERS
$10,000
WELDERIES
$22,800
FUNCTIONAL MACHINERY
$22,800
INDUSTRY MACHINERY
$10,000
MAINTENANCE
$22,800
3 MAIN PROGRAM AWARDS
$22,800
HONORABLE MENTION AWARDS
PREPARED BY THE JAMES F. LINCOLN ARC WELDING FOUNDATION—41940

18 HOURS FROM SLAB TO FINISHED GEAR

with welded, rolled steel construction

THIS large gear with a pitch diameter of seven feet five inches and a six-inch face, for use on a six-foot rotary kiln, was fabricated by the Manufacturers' Steel Supply Co. in record time by welding rolled steels. It could not have been produced by any other method as quickly or cheaply.

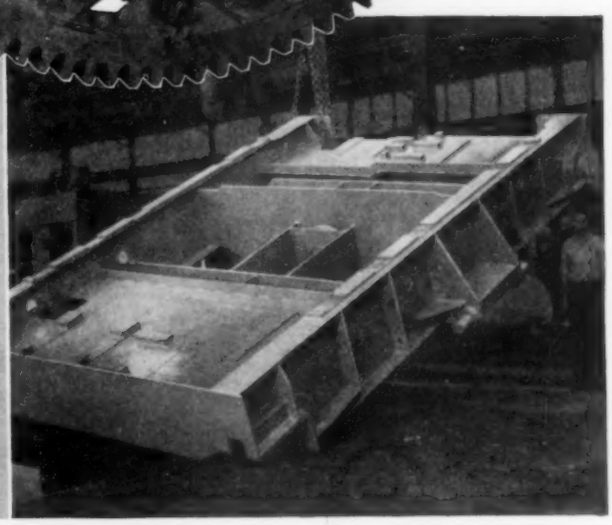
However, greater by far than the advantage in time saving, is the new freedom welded construction has given to the industrial designer. Limited only by functional requirements, he can suit his steels to each particular part, effect any combinations and include castings where expedient. The result: greater efficiency, longer life, better-looking equipment and at generally lower cost.

Supplying rolled steels in the complete range needed is our specialty. The list is imposing. U·S·S COR-TEN for corrosion resistance. U·S·S COR-TEN and U·S·S MAN-TEN for strength without excessive bulkiness or weight, U·S·S Abrasion Resisting steel for parts that need extra wear resistance. U·S·S Heat Resisting steel efficient under temperatures ordinarily disastrous. U·S·S Carilloy Alloy Steels for heavy bearing pressures.

Our steel specialists will be glad to show you how these steels can be used to best advantage. Their advice and assistance is yours without obligation. Why not check with them to keep abreast of the latest metallurgical improvements?

USING THE RIGHT STEEL IN THE RIGHT PLACE

Man-Ten Crane Trolley weighs less. *With tensile strength of 80,000 lb. per sq. in. min., and yield point of 50,000 lb. per sq. in. min.,* MAN-TEN *construction reduces weight far below conventional construction yet gives this trolley the safety that crane equipment demands.*



CARNEGIE-ILLINOIS STEEL CORPORATION, *Pittsburgh and Chicago*
COLUMBIA STEEL COMPANY, *San Francisco*
TENNESSEE COAL, IRON & RAILROAD COMPANY, *Birmingham*
United States Steel Export Company, New York

UNITED STATES STEEL

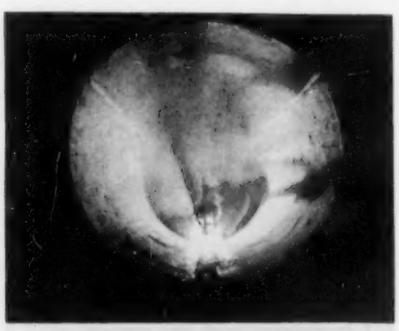
ALUMINUM TANK CARS

Automatic carbon-arc welding is reported to have many advantages in the construction of aluminum tank cars at the American Car and Foundry Company Plant, Milton, Pa. The automatic process permits faster construction and a considerably better quality weld together with marked freedom from distortion. This development was motivated by a desire to improve quality, not to lower costs which are practically unchanged due to the increased flux cost canceling the labor saving.

Since no beveling of plate edges is required, the full thickness of metal is utilized in the welding by simply butting the square edges together, greatly simplifying the set-up of the work. The welding time per tank is noticeably shorter than previous methods since the automatic weld is made in two passes instead of three formerly used. The fact that automatic welding permits welds of complete overlapping penetration accounts for the greatly improved quality of the weld.

Freedom from distortion, which has been a factor in previous methods of fabricating aluminum, is permitted with the automatic carbon-arc method because of a faster welding this process makes possible. Very little straightening is required on round tanks welded by this process whereas, with the previous method, considerable straightening was necessary. This advantage not only simplifies production of the shell itself, but, because the shell is so uniformly round, the heads are readily fitted to the ends of the shell.

Fig. 1—Welding an Inner Longitudinal Seam of an Aluminum Tank Car by Lincoln Tractor-Type "Electronic Tornado" Carbon-Arc Welders at American Car and Foundry Company, Milton, Pa.



Photos courtesy Lincoln Electric Co.

Fig. 2—Welding a Head in an Aluminum Tank by the Automatic Carbon-Arc Process at American Car and Foundry Company. The Tractor-Type Automatic Welder Remains Stationary While the Tank Is Rotated Underneath the Arc

Accompanying illustrations show the use of automatic carbon-arc welding in fabrication of aluminum tank cars at American Car and Foundry Company. In Fig. 1 can be seen a tractor-type "Electronic Tornado" automatic carbon-arc welder welding an inner longitudinal seam in an aluminum tank. In Fig. 2 the "Electronic Tornado" tractor is welding a head in one of the aluminum tanks.

Materials used in constructing tank cars of aluminum include: a bottom plate $^5/_8$ in. thick; two sides, or top, plates $^1/_2$ in. thick; and two heads $^5/_8$ in. thick. The tanks are 78 in. outside diameter and 32 ft. over-all length.

Square-edge tight butt welds are used throughout in construction. The difference in thicknesses of the butting edges is taken care of by maintaining uniform outside diameters and making up the difference by an off-set on the inside of the tank.

Three longitudinal welds two consisting of $^1/_2$ in. to $^5/_8$ in. and one of $^1/_2$ in. thickness are required in constructing the shells. Two passes, one inside and one outside, are required for each longitudinal seam. The first longitudinal pass is made on the inside with the seam properly backed up with a water-cooled copper chill bar, giving complete penetration with one pass. The second pass, made on the outside, is applied to obtain overlapping penetration and for the sake of appearance. It is made without any backing up.

In welding the heads to the shell, the head is fitted and the tank rotated under the carbon arc which welds the outer seam with the inside properly backed up with copper chill bars. Filler metal for the weld is supplied by $^1/_4$ in. aluminum wire fed into the arc. The second pass on the head weld is done manually after grooving with a chipping tool.

The aluminum tanks manufactured by the American Car and Foundry Company have for the most part, been utilized for glacial acetic acid service. This is the basic material for the manufacture of rayon and non-inflammable film. Two of the aluminum tanks have also been put into service for carrying peroxide. These were constructed of 2-S (99.5% aluminum). The balance of the tanks, for acetic acid service, were constructed of 3-S aluminum (97.5% aluminum).

FEDERAL MACHINE APPOINTMENT

Chas. J. Martin has recently been appointed chief engineer of The Federal Machine and Welder Company of Warren, Ohio, bringing to this company a wide experience in the designing and building of high-production precision machine tools, special machines and equipment, along with a vast experience in the resistance-welding equipment field. Mr. Martin is a graduate mechanical engineer and along with his technical training, is a practical mechanic, having spent considerable time as a machinist and tool-maker in the automobile plants.

Prior to coming to The Federal Machine and Welder Company, Mr. Martin was

Charles J. Martin

assistant chief engineer of the Ford Motor Company from 1923 to 1934, having had charge of the designing of all production equipment, including special machines, fixtures, dies, gages, ovens, welding equipment, conveyors and plant layout. From 1934 to 1940 Mr. Martin was affiliated with the Ex-Cell-O Corporation of Detroit in the capacity of machinery salesman and sales engineer.

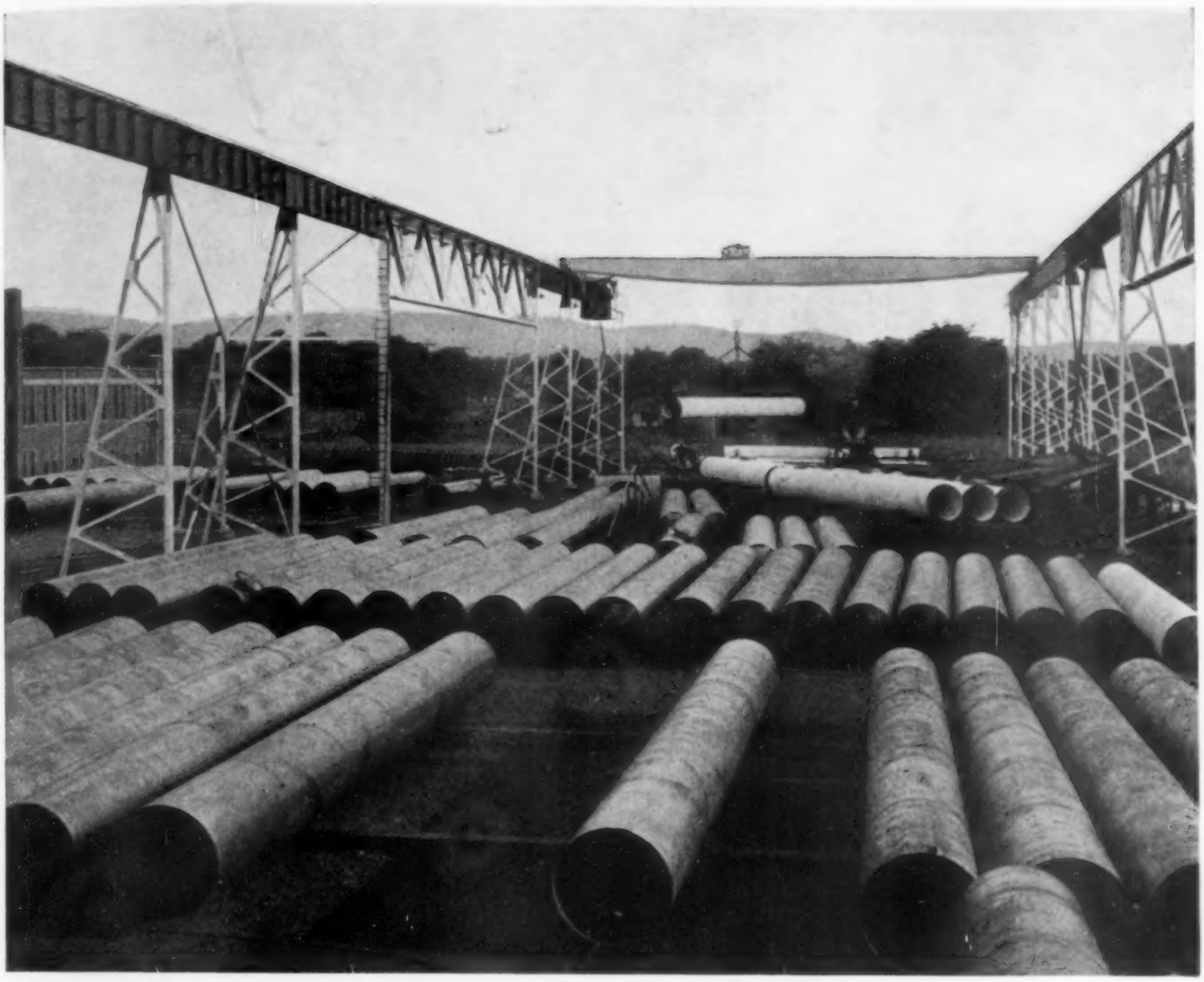
INDUSTRIAL PHYSICIANS AND SURGEONS MEETING

The 25th Annual Meeting of the American Association of Industrial Physicians and Surgeons, together with the 1st Annual Meeting of The American Industrial Hygiene Association, will be held at Hotel Pennsylvania, New York City, June 4, 5, 6, and 7, 1940. This will be a four-day Convention intensively devoted to the problems of industrial health in all of their various medical, technical and hygienic phases, with particular stress on prevention and control of occupational hazards. Important programs have been prepared, and technical and scientific exhibits will be a feature of the Convention. The Dinner on Thursday evening, June 6th, will be the occasion of the presentation of the Wm. S. Knudsen award for the year of 1939–40. All who have an interest in these phases of industrial health including industrial hygienists, safety engineers, chemists, plant engineers and personnel managers, are urged to attend as this program will have unusual value to all these groups.

1940 A. S. T. M. ANNUAL MEETING

Symposiums and Special Sessions to Feature Forty-Third Annual Meeting in Atlantic City, June 24 to 28, 1940

In order to provide ample time for the presentation and discussion of the large number of technical papers and reports to be presented at the 1940 Annual Meeting (Forty-Third Annual Meeting of the American Society for Testing Materials to be held at Chalfonte-Haddon Hall,



STEEL PIPE

. . . . of welded construction

Where large diameter pipe lines are to be subjected to high pressures, waterworks engineers are now specifying welded steel plate construction in order to obtain the required strength. The flexibility and high tensile strength of steel plate pipe reduce the danger of breaks which interrupt service and are costly to repair. Steel pipe can be fabricated in long lengths which reduces the number of field joints and cuts down installation costs. Field joints remain tight, and centrifugally applied coatings give the pipe long life and high carrying capacity. The above illustration shows part of the 40 miles of steel pipe which was used on the Birmingham Industrial Water Supply Line.

CHICAGO BRIDGE & IRON COMPANY

Chicago	2455 Old Colony Bldg.	Birmingham	1507 North 50th Street	Philadelphia	1668-1700 Walnut St. Bldg.
New York	3398-165 Broadway Bldg.	Tulsa	1654 Hunt Bldg.	Boston	1565 Consolidated Gas Bldg.
Cleveland	2282 Rockefeller Bldg.	Houston	2919 Main Street	San Francisco	1097 Rialto Bldg.
Dallas	1489 Liberty Bank Bldg.	Detroit	1556 Lafayette Bldg.	Los Angeles	1455 Wm. Fox Bldg.

Fabricating plants in CHICAGO, BIRMINGHAM, and GREENVILLE, PA.

Atlantic City, N.J., June 24th to 28th, incl.) twenty-two separate sessions are being arranged, with several symposiums and certain groups of technical papers indicating a strong technical program of widespread interest.

Throughout the week of the meeting the Society's Annual Photographic Competition will be in progress.

Important sessions will include the Symposium on Tools of Analytical Chemistry, Symposium on the Significance of the Tension Test in Relation to Design, Symposium on Spectrochemical Analysis, Symposium on Problems in the Classification of Natural Waters Intended for Industrial Use, and separate sessions devoted to radiographic testing, cement, concrete, petroleum products, non-ferrous metals, and plastics.

DOCKING FLOAT BUILT IN RECORD TIME

A new speed record for construction of steel-welded river craft was established at Dravo Corporation's Neville Island shipyards early in April 1940, with the completion, in only 14 days, of a 175 ft. x 26 ft. x 6 ft. landing flat for the Lawrence Pipe Line Company.

In order to begin promptly a new river operation involving the shipment of gasoline by barge from its terminal at Mt. Vernon, Indiana, to various river points, the Lawrence Pipe Line Company required the landing flat to be delivered in not more than 45 days. When the contract was awarded on Friday, March 29th, a force of ten draftsmen was assigned to the job of completing the drawings required. These drawings were ready by Saturday, March 30th, and fabrication of steel from the Dravo stock was begun the next day.

The production plan divided the structure into 56 shop units, 22 deck sections, 22 bottom sections and 12 side sections. These were fabricated, fitted and welded into preassemblies, then moved to the barge shop for final assembly.

By April 4th, six days after the order, these shop units were far enough along to allow the final assembly to begin. In the enclosed barge shop at Neville Island it was possible for the fitting and welding of the final assembly to go on 24 hours a day, without interference from adverse weather conditions. In this way the 56 subassemblies were joined and completely welded in accordance with the rules of the American Bureau of Shipping, by April 12th, fourteen days after the contract was signed.

There is no record of any previous floating structure of this size on which all work was completed in such a short time period.

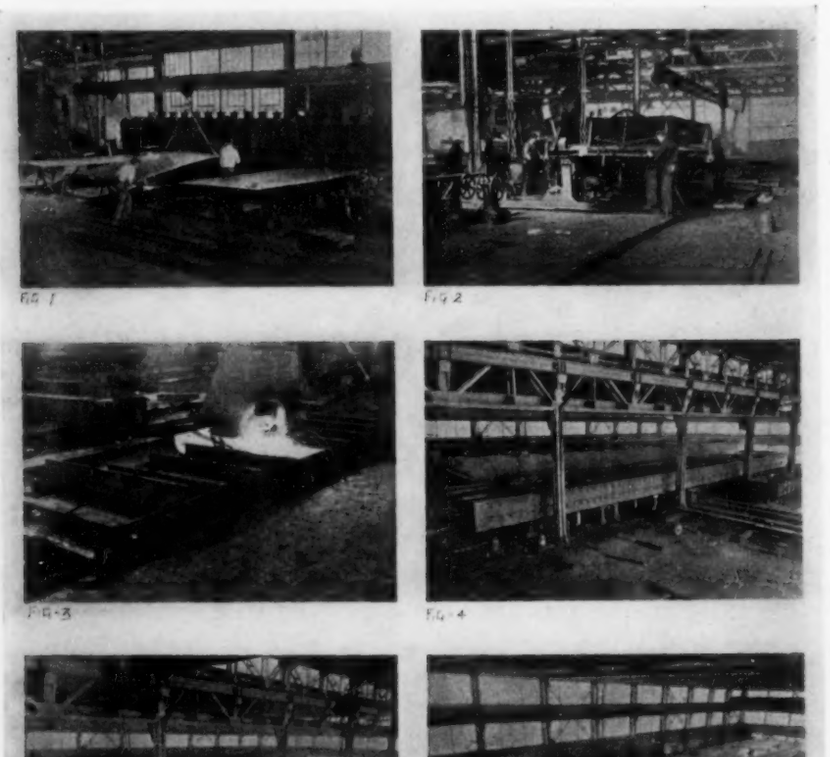


Fig. 1—Status of Record-Breaking Float Construction at Dravo Corporation on April 1st. This Craft Was Completed in 14 Days from Contract Date. Illustration Shows Processing Plates in Plate Planer

Fig. 2—Bending Plates for Landing Float

Fig. 3—Welding in the Structural Shop

Fig. 4—Status of Record-Breaking Float Construction at Dravo Corporation on April 5th Showing Float Partially Completed

Fig. 5—Status of Record-Breaking Float Construction on April 8th Showing Float Nearing Completion

Fig. 6—Status of Record-Breaking Float Construction on April 12th Showing Completed Float

NEW BULLETIN ON WELDING ELECTRODES

A.C. and D.C. "Crucible-Weld" Flexare Welding Electrodes, for every industrial requirement, are described in a new 12-page illustrated bulletin just announced by the Westinghouse Electric & Manufacturing Company. Electrodes for the welding of various classes of mild carbon steel, cast iron, stainless steels, aluminum, copper and its alloys, and manganese, and electrodes suitable for arc cutting and hard surfacing are listed.

Physical properties and uses of each electrode and various types of welds produced are discussed in full; comments are given on solution of minor welding difficulties. Included in the bulletin are tabulations of the available lengths, weights, approximate number of rods per pounds and recommended welding current values for the various electrodes.

Copies of Descriptive Data 26-645 may be obtained from Department 7-N-20, Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

OBITUARY

D. B. Rushmore

David Barker Rushmore, who was chief engineer of the power and mining department of the General Electric Company at Schenectady for twenty years before his retirement in 1925, and who played a major part in bringing about American participation in the world power conference, died in the Post Graduate Hospital after a fortnight's illness. Mr. Rushmore was 66 years old and lived in Washington, Conn.

He was born in Old Westbury, L. I., on August 21, 1873, and was educated at the Friends Academy, Locust Valley; Swarthmore Preparatory School and Swarthmore College, from which he was graduated in 1894, and from which he held the degrees of B.S., C.E., and honorary Dr.Sc., and Cornell University, from which he obtained his M.E. in 1895. At Swarthmore he won the Joshua Lippincott Fellowship.

Mr. Rushmore was one of the founder members of the AMERICAN WELDING SOCIETY. He was active in the work of the Welding Committee of the Emergency Fleet Corporation and an important factor in the organization of the Society.

"Why Lad, when I was your age that Addressograph was the last word."

"So was the nickelodeon, Pop. But the last word today is Progress."

"Maybe, Lad, but that old 'Addressograph' was a humdinger. Just give her the gun and, presto, your envelope was addressed and the next name on the belt shifted into place. THAT was Progress, Lad!"

"Fine, Pop. But this new 'Addressograph' turns out pay-rolls, tax applications, billing forms and other records—and its welded steel printing arm puts it years ahead in speed and quality of work."

"You're prejudiced for welding, Lad. I'm from Missouri."

"I'm prejudiced for Progress, Pop. I can show you sharper, more uniform printing and 10 good carbon copies per impression where it used to be 3, because deflection of the printing arm has been cut from .018 inch to .003 inch by going to welded steel."

"I'd say that's arming for increased sales, Lad. But I'd like to see the model they bring out when you're my age. Bet yours of today will then bring on the smiles like my old timer."

"You'll see Progress a'plenty before that, Pop. Many designers are just starting to go places with welding."

"But suppose my route to Progress isn't via *increased rigidity* of a printing arm."

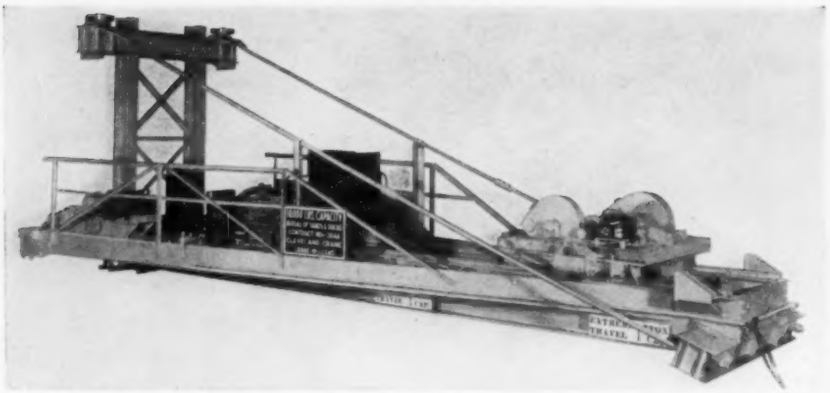
"OK. Regardless of what metal product you manufacture, you can make headway via *increased strength, reduced weight, improved appearance, quicker deliveries* or *lower operating costs*. And you can take the bee-line by lining up with the A-1 welding line of THE LINCOLN ELECTRIC COMPANY, Dept.DD-25, Cleveland, Ohio. Largest Manufacturers of Arc Welding Equipment in the World."

FORMER MODEL. This "Addressograph" has been superseded by the streamlined, welded steel design shown. Parts such as the vertical magazine have been moved away from the printing path for greater operating speed and wider range of application.

1/6 THE DEFLECTION. Above: former cast iron printing arm and base assembly. Weight 170 lbs. Deflection .018 inch. Below: new welded steel printing arm and base unit with box section as shown at left. Weight 70 lbs. Deflection .003 inch.

ELECTRODE PROGRESS. In line with Lincoln's progressive policy of ever reducing the cost of welding, this Company recently announced reductions up to 1/2c per pound for "Fleetweld"—the world's most popular welding electrode. Write for latest price list.

HOW TO MAKE HEADWAY. This 20-page bulletin gives valuable suggestions for welded design. Includes experiences of scores of executives and engineers. Shows a large number of actual welded parts of various types. Write for your free copy today.



WALL CRANES

The Cleveland Crane & Engineering Company, Wickliffe, Ohio, recently furnished six wall-type cranes of interesting construction to the Navy Department, Bureau of Yards and Docks for Norfolk Navy Yard, Portsmouth, Virginia.

The cranes have a horizontal reach of thirty feet from center of hook to center of runway rails. They have a capacity of five tons at twenty-foot reach and three tons at thirty-foot reach. The total lift is twenty-two feet.

The jib travel speed is 200 f.p.m., trolley speed is 75 f.p.m. and the hoisting speed 30 f.p.m. Four motors are used; two for the jib travel and one each for the other motions.

The cranes are of the all-welded steel construction with roller bearings throughout. Six wheels are provided for the jib travel; two for the vertical loading, two at the base of the crane for the wall compression loading, and two upper wheels for the wall tension loading.

The jib travel is by means of two individual duplicate drive units which operate simultaneously. Magnetic control is provided for all motors. Control is floor-operated push-button type.

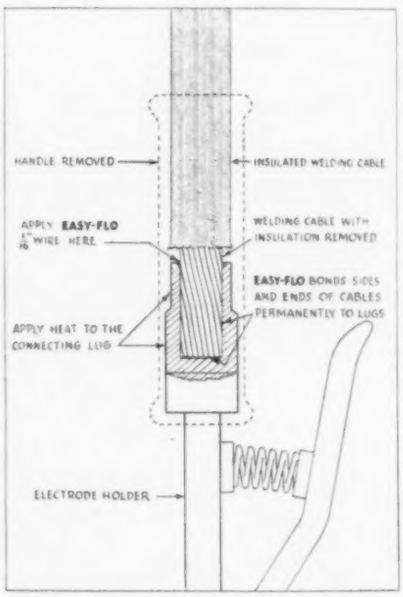
Wall cranes of this type are especially suitable for local operations under heavier overhead traveling cranes or for places where it is not practical to build a conventional two-track overhead runway.

A CURE FOR HOT HANDLES ON ELECTRODE HOLDERS

While arc welding with a $^1/_4$-inch diameter rod an operator was bothered by excessive heat in the electrode holder handle. An inspection showed that the soft soldered connection between the holder and welding cable had melted. Naturally, the poor electrical contact built up excessive heat rapidly. The trouble was cured permanently by rejoining the cable and holder with a silver brazing alloy.

The solder was first melted off the cable and holder. Then these parts were cleaned thoroughly and fluxed with a low temperature brazing flux. After re-assembling the joint, heat was applied with an oxy-acetylene torch, concentrating it upon the connecting lug of the electrode holder.

As the lug and cable fitting into it came to a dull red heat, a low temperature brazing alloy known as Easy-Flo was applied as indicated on the accompanying sketch. About 4 or 5 inches of $^1/_{16}$-inch wire flowed in and around the cable, solidifying


HANDLE REMOVED
INSULATED WELDING CABLE
APPLY EASY-FLO 1/16" WIRE HERE
WELDING CABLE WITH INSULATION REMOVED
EASY-FLO BONDS SIDES AND ENDS OF CABLES PERMANENTLY TO LUGS
APPLY HEAT TO THE CONNECTING LUG
ELECTRODE HOLDER

it and joining it firmly to the holder. No further trouble with heating was experienced and the operator found that he could concentrate full attention far better on the work to be done.

From cost estimates it has been determined that brazing alloy and gases to make a joint of this kind do not exceed 5 cents. By heating slightly above the flow point of the brazing alloy, (1175° F.) a joint can be easily taken apart if necessary.

INDUSTRIAL PYROTECHNICS

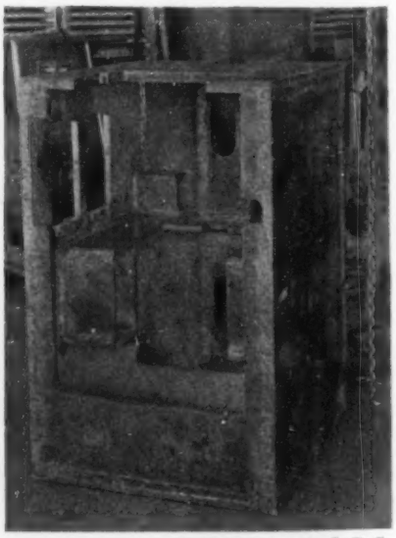
Not a Fourth of July display but a huge fan of flying sparks caused by a flash-welding process. The spectacle is created in the General Electric Company's Lynn Works as two semi-circular pieces of steel are fused into a magnet-frame for a direct current electric motor. Asbestos curtains hanging from 30 feet above the floor restrict the sideward flight of the sparks shooting from the welder.

Industrial Pyrotechnics

WELDING SAVES COST OF MOLD

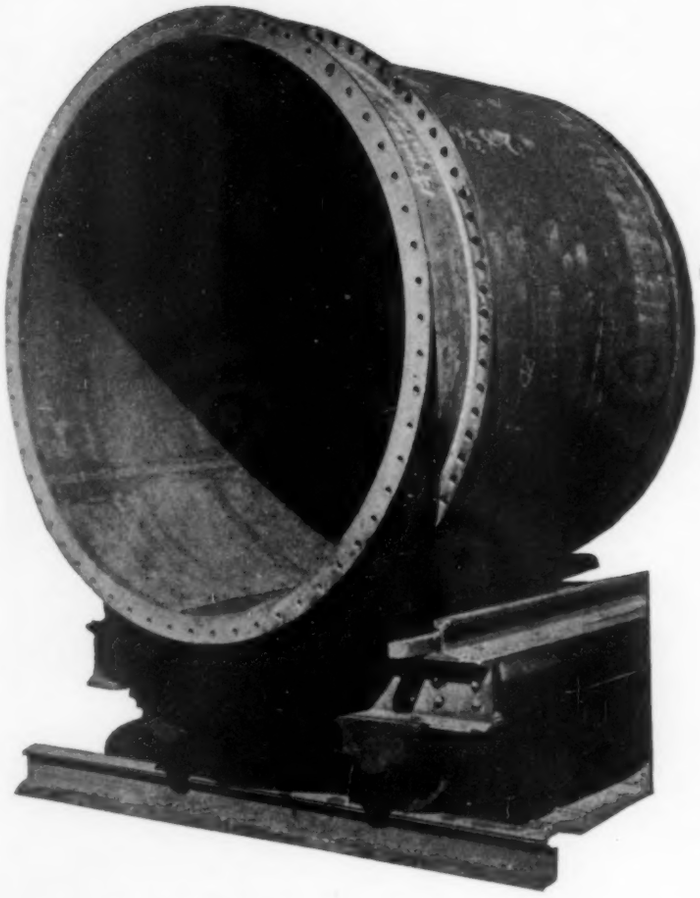
Just fifteen hours were required to produce. . . with welding. . . this complicated, 1600-pound machine base. The expense of making a complex mold to produce this base by casting would have made the cost excessive. The arc-welded base was fabricated by the Menna Welding Company of Toledo, Ohio, using a 500-ampere a.-c. welder.

Parts of Machine Base to Be Arc-Welded



Photos courtesy G. E. Co.

Arc-Welded Fabricated Machine Base



Made of
SOLID NICKEL ...ALL-WELDED
Construction

Nickel reactor 72 inches diameter x 72 inches deep fabricated from 11/16 inch solid Nickel. Below is view of complete assembly with steel jacket in place.

Electric welded reaction vessel of Nickel plate 11/16 inch thick

A job to test a welder's mettle...and test the metal employed...is this solid Nickel reaction vessel. Made of 11/16 inch plate, it is built in accordance with A.S.M.E. code requirements.

What procedure was followed to assure strong, sound welds? First, the right rod was employed...No. 131 Nickel Arc Welding Rod. Second, before the job was started, test welds were made. Subjected to X-ray inspection, and to tensile and bend tests, they proved that both solid Nickel and weld metal were acceptable.

On jobs in Nickel or any of the Nickel-base alloys there's a way to assure easy welding and sound welds: Use the proper materials...as shown in the table below, and use the proper welding procedure. Clip this table and keep it for future reference. For further information write to: The International Nickel Company, Inc., 67 Wall Street, New York, N.Y.

PHYSICAL PROPERTIES OF TEST SPECIMENS

SPECIMEN	*Width and Thickness*	*Unit Load – P.S.I. Yield Strength*	*Ultimate*	*Elongation*	*Specific Gravity*
NICKEL PLATE	11/16 in. thick	44,000	73,600	40% in 8 in.	8.85
WELDED NICKEL JOINT No. 1	.645 wide x .614 in. thick	55,000	77,700		
No. 2	.637 wide x .611 thick	51,400	77,400		8.7
ALL WELD METAL	½ in. diam.	50,000	88,700	25% in 2 in.	
FREE BEND Face and Root				30% min. No fractures	
X-RAY	X-Ray pictures showed weld to be well within Code Requirement for porosity and to contain no slag inclusions or lack of fusion.				

INCO WELDING RODS and FLUXES

MONEL

Oxy-Acetylene . . . No. 40 Monel Gas Welding Rod—Monel Gas Welding Flux.

Metal Arc . . . No. 130-X Monel Metal Arc Welding Rod.

NICKEL

Oxy-Acetylene . . . No. 41 Nickel Gas Welding Rod—no flux is used.

Metal Arc . . . No. 131 Nickel Metal Arc Welding Rod.

INCONEL

Oxy-Acetylene . . . No. 42 Inconel Gas Welding Rod—Inconel Gas Welding Flux.

Metal Arc . . . No. 132 Inconel Metal Arc Welding Rod.

NICKEL-CLAD STEEL

Metal Arc . . . No. 135 Nickel Metal Arc Welding Rod.

NICKEL

NEW PRODUCTS

The Society assumes no responsibility for the validity of claims in this Section

HELMET WITH HIDDEN HINGE

Sellstrom Manufacturing Co., Chicago, has recently introduced a welders' helmet made of a new material that very effectively insulates against heat and weighs only fifteen ounces complete with lens and holder, as against the usual twenty ounces or more of the average helmet.

LIGHT-WEIGHT, RUST-PROOF ALLOY

The Colonial Alloys Company of Philadelphia, Pa., whose light alloys were announced some time ago are now offering their No. 301 Alloy. Characteristics of this alloy as recorded by Tinius Olsen Testing Machine are as follows:

Ultimate tensil:	72,110 lb. per sq. in.
Elongation per cent in 2 in.:	32
Yield Point:	57,530 lb. per sq. in.
Reduction of area per cent of original section):	16.5
Brinell:	109

This Alloy has good forming and drawing qualities and is absolutely rust-proof.

Colalloy No. 301 lends itself to gas welding, spot welding, seam welding, arc welding, brazing, soldering, Colawelding (fusion welding chemically) and reaction soldering.

The thermal and electrical conductivity factors are good, as well as the corrosion resistance factors.

The metal polishes to a beautiful, lustrous, silvery, chrome-like appearance. Also, it is non-magnetic and non-sparking.

The light-weight factor of Colalloy No. 301 is important. It is approximately 66% lighter than steel or iron and 70% lighter than brass, copper, nickle, bronze or their alloys. Its high weight-strength ratio makes this metal rather unusual.

ALLOYING A DEPOSITED METAL TO METALS

Simple application, efficient bonding, high metal-protection factor and low costs give the simplest description of *Colaweld Mormetal.*

Simple application requires only two operations:

(*a*) Applying *Colaweld Mormetal* (by spray, brush or powder);
(*b*) Applying heat (by torch, oven or other means).

Efficient bonding is due to a combination action of adhesion and fusion applying with the surface of the base metal.

High metal-protection factor is evident by a high increased resistance to:

(*a*) Corrosion;
(*b*) Abrasion;
(*c*) Erosion, a successful 800-hour, salt-spray test has been reported on a recent *Colaweld Mormetal* application.

Low cost is demonstrated by:

(*a*) Low first cost of *Colaweld Mormetal* material;
(*b*) Low cost of application;
(*c*) Low cost of heating (low heats required).

The low heat required does not tend to burn, twist or anneal the base metal.

The thickness of metal deposit can be regulated by the use of simple procedure.

Zinc, cadmium, tin, bismuth, lead or their alloys are among some of the metals that can be applied in this manner. They may be applied to most any metal, ferrous or non-ferrous, as well as to welded, soldered or brazed sections or joints.

Additional information may be had on request to Colonial Alloys Company, Colonial Philadelphia Building, Philadelphia, Pa.

SPOT WELDER

The Eisler Engineering Company of Newark, New Jersey has introduced a 5 kva. high speed production Spot Welder. This welder is an air operated, vertical press type machine supplied with a suitable automatic timer and contactor.

There are two operators for this welder, one to load the welding fixture and the other to operate the foot switch and slide the fixture along after each weld.

The objects shown in the photo are cylindrical shaped tubes, to which small flat pieces of metal are being spot welded. The operator can attain a speed of 150 spots per minute.

This machine will easily adapt itself for many other types of spot welding jobs.

"QUICK HEAT" SOLDERING IRON

Soldering heat in less than a minute is the claim for a new soldering iron just announced by the Ideal Commutator Dresser Co., 1938 Park Avenue, Sycamore, Illinois.

Through the use of a special carbon electrode heating element, an entirely new principle in electric soldering iron design, the tip is quickly brought up to soldering temperature. The carbon electrode makes contact at point of tip so that heat is concentrated where it is most effective.

Heating is controlled by a thumb-operated button on the handle and continues as long as the button is held down. Heating stops when the button is released, thus current is used only when control button is held. No damage can be caused by accidentally leaving the unit plugged in.

CALCULATOR

The Champion Rivet Company has prepared a Calculator of welding costs in the form of a slide rule, and in a handy pocket size.

This instrument is unusual in that it appears to be the first attempt to display in chart form a set of welding cost standards which can serve as a guide to engineers and plant officials on their production welding where a definite and normal procedure is being followed.

It is being distributed through all the sales offices of the company at a nominal charge.

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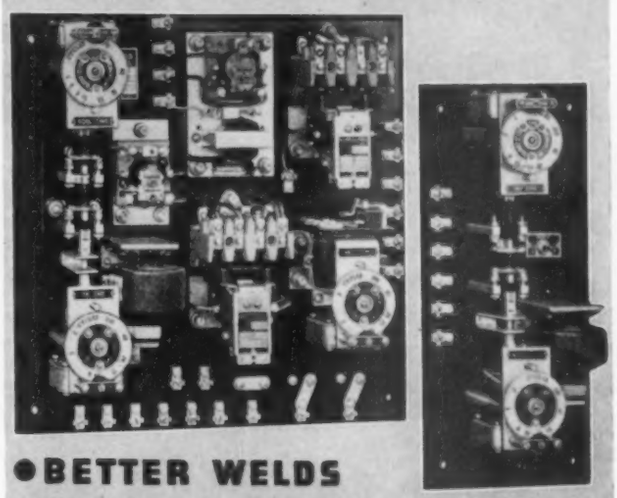
Pipe Lines. Recommendations for Stove-Piping and Roll-Weld-

Automatic Control

OF INTERRUPTED SPOT WELDING WITH

SQUARE D

CONTROLLED INTERVAL TIMERS



● BETTER WELDS
● LONGER ELECTRODE LIFE
● INCREASED MACHINE CAPACITY

Interrupted spot welding consists of breaking the flow of current at controlled intervals while the electrodes remain clamped to the work. The process has advantages in the fabrication of thick cross sections, unusual shapes and hot rolled materials because—

1. Alternate heating and cooling intervals raise the metal to fusion temperature without overheating and annealing the electrodes. Reduces maintenance cost.
2. Brittle welds are avoided and the effect of scale or rust on the material surfaces is minimized. Better product.
3. Welding machine capacity for thicker materials is increased by applying several smaller current impulses in place of a single one of high value. Smaller machine investment.

The new Square D timer panels for air-operated welding machines can be equipped to automatically control the Heat and Cool periods of interrupted spot welding as well as the Squeeze, Hold and Off periods of the welding cycle. Pneumatic time delay mechanisms and high speed relays are interconnected in a circuit arrangement which eliminates sensitive adjustment and provides independent control of all functions. Similar timers are available for foot-operated and motor-driven machines.

Square D timers and welder panels are not costly and are easy to operate. *Write for Bulletin 38-017.*

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» » » SECTION ACTIVITIES « « «

CLEVELAND

The Cleveland Section Annual Welding Conference was an outstanding success this year. Held at Statler Hotel Cleveland, Ohio, May 3, 1940, starting at 2 P.M. and continuing through dinner until well into the evening the Conference had a registration of over 450 with 200 for the afternoon sessions and 350 for the evening session which followed dinner for almost 240 happy weldmen.

The program in the afternoon included talks by John J. Crowe, Asst. to Vice-President, Air Reduction Sales Co., on "Cutting and Machining with Oxyacetylene Torch;" J. H. Zimmerman, Development Engineer, The Linde Air Products Co., on "Flame Hardening, Flame Softening, Flame Strengthening;" George A. Jessop, Chief Engineer, S. Morgan Smith Co. on "Economic Production of Heavy Mechanical Equipment by Use of Welding and Cutting."

Mr. Ernest E. Thum, editor of *Metal Progress*, served as chairman for the afternoon.

The evening session following the dinner was very ably addressed by Dr. J. C. Hodge, Chief Metallurgist, Babcock Wilcox Company of Barberton, Ohio, on "The Metallurgy of Arc Welding."

Mr. Fred L. Plummer, consulting engineer and chairman of the Cleveland Section, presided as chairman of the evening session.

The success of the Conference was due to the untiring effort of Conference Committee Chairman, Mr. Frank Maine, Chief Engineer of Republic Structural Iron Works, and his committee which include Mr. Harold Blum, Mr. Arthur Markee, Mr. Joseph Driscoll, Mr. J. S. McKeighan, Mr. John Austin and Mr. W. C. Heinle.

The larger steel plants, fabricating and industrial companies and welding suppliers without whose excellent cooperation the conference could not possibly have been so successful, included such concerns as American Steel and Wire, Republic Steel, Otis Steel, Contract Engineering Corp., Wellman Engineering Co, Republic Structural Iron Works, American Shipbuilding Co., Ohio Machine and Boiler Co., Champion Rivet Co., Goodyear Tire and Rubber Co., Linde, Airco, Una Welding, National Cylinder Gas Co., Maurath, Inc., Burdette Oxygen, General Electric, Lincoln Electric, Harnischfeger, Hobart Bros. Co., Williams & Company, Cleveland School of Welding, Universal Power Corp. and many, many other nationally known concerns interested directly or indirectly in the welding process.

Due to the enthusiasm demonstrated at this Conference, the Cleveland Section has decided to have a similar meeting in May 1941, to which all those interested in welding are invited.

HAWAII

The Hawaii Section held a meeting on January 25th at the Von Hamm Young Co., with an attendance of 53 members and guests. A short business meeting was held during which Messrs. C. M. Ryan, H. T. Lee and J. K. Mardick were appointed to act as a committee to work with the Dept. of Vocational Education and Mr. Harvey Freeland, in setting up a code by which technical schools teaching welding should operate.

Another meeting of the Section was held on March 28th at the Pacific Club, with an attendance of about 25 members and guests.

Mr. C. M. Ryan gave a report of the committee assigned to work with the Department of Vocational Education, in which he stated an outline had been presented covering 1200 hours of welding instruction. A short discussion followed.

The speaker of the evening was Mr. Harold Fleck, metallurgist at Pearl Harbor, who gave a very interesting talk on the weldability of metals, after which a lively discussion took place.

KANSAS CITY

On April 11th the Kansas City Section had a very interesting dinner meeting at Fred Harvey's Restaurant, Union Station. Mr. A. E. Gibson, president of the Wellman Engineering Company, Cleveland, was the speaker and presented a very interesting paper on "Proper Preparation of the Work to Be Welded." There was also the showing of a moving picture on "Norton Abrasives."

LOS ANGELES

The regular meeting of the Los Angeles Section was held on April 18th. Mr. H. V. Thaden, Sales and Development Engineer, Stainless Steel Division, Carnegie-Illinois Steel Corporation, presented an illustrated talk on "Stainless Steel in Aircraft. The importance of stainless steel as a material for plane construction due to its weldability in addition to its physical properties was well brought out in Mr. Thaden's talk. An interesting discussion period devoted mainly to descriptions of various types of spot and resistance welders followed the regular talk.

The talk was preceded by dinner and the usual business meeting of the Section. Secretary Gowing delivered a report on the educational course recently completed. The report showed an average attendance of 150 at each meeting during the course and revealed that the financial outcome was eminently satisfactory.

MARYLAND

The Maryland Section reports the election of the following Officers for the coming term.

Again **EASY-FLO** *proves the answer to a difficult brazing job.*

JOINING thin tubes to a center casting of this electric urn heater is "one of the most difficult jobs we have had", say the Harold E. Trent Company, makers of electrically heated industrial equipment.

All 16 joints are brazed simultaneously. Being an immersion unit, all joints must be *watertight* to protect the electric heating elements inside the tubes . . . and they must be *strong*, for pressures may go as high as 100 pounds . . . and they must be *ductile* to withstand the strains of repeated heating and cooling.

EASY-FLO does this brazing job to the manufacturer's complete satisfaction. At the low temperature of 1175 deg. F. it penetrates between the closely fitted parts to make sound, smooth appearing joints at low cost.

As the diagram shows, tubes may be copper or a steel alloy. EASY-FLO is equally effective in either case. It brazes ferrous or non-ferrous metals and is particularly effective for joining dissimilar metals.

EASY-FLO is doing fast, reliable, low cost work for a rapidly growing number of manufacturers. Have you tried it on your metal joining work? Write for full details and Bulletin WJ-106.

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Chairman, Roy A. Mansfield, Southern Oxygen Co.; Vice-Chairman, John Cumberland, Arc-Way Equipment Co.; Secretary-Treasurer, W. M. H. Ballantyne, Penna. Water & Power Co.

On April 19th, Mr. A. C. Simpson, Metallurgist, Titan Metal Mfg. Co., Bellefonte, Pa., showed a motion picture on the manufacture of bronze-welding rods and the weldability of same.

The next meeting of the Section will be held in October.

MILWAUKEE

The April meeting of the Milwaukee Section was held on the 26th. Mr. R. D. Thomas, President, Arcos Corporation, Philadelphia, presented a welding address on the subject, "Stainless Weld Metal and the Welding of Stainless Steels."

NEW YORK

The Annual Meeting of the New York Section was held on Tuesday, May 14th. It was preceded by a meeting of the Executive Committee of the New York Section. The meeting was held in the Engineering Societies Building. Mr. J. W. Sheffer, Electrical Engineer, American Car and Foundry Company was the presiding officer. Two excellent papers were presented. The first dealt with "Welding in the Aircraft Industry," by L. P. Wood, Head, Materials Department, Aviation Manufacturing Corp., Stinson Aircraft Division. Mr. Wood touched on the various processes used in aircraft welding and dealt specifically with resistance welding in the aircraft industry.

The second paper was by Mr. Stanley M. Humphrey, Chief Electrical Engineer, Taylor-Winfield Corporation, on "Energy Storage Resistance Welding." Mr. Humphrey's paper, which was illustrated by lantern slides, dealt with the underlying principles and advantages of capacitor type resistance welding and the equipment employed.

Chairman Kandel announced that the New York Section would have a World's Fair Day on Saturday, June 8th, and that Mr. S. S. Scott would be the chairman of the committee on arrangements.

Representing the Tellers Committee, Mr. E. Vom Steeg announced the election of the following officers for the next year.

Chairman, J. T. Phillips, Foster Wheeler Corp.; *First Vice-Chairman*, E. V. David, Air Reduction Sales Co.; Second Vice-Chairman, B. A. Russell, Federal Shipbuilding & Dry Dock Co.; Secretary-Treasurer, Wayne A. Howard, Socony-Vacuum Oil Corp.; Executive Committee (Term 3 years)—C. W. Bryan, Jr., J. W. Sheffer, E. Vom Steeg, C. Kandel.

Upon the adjournment of the meeting refreshments were served to all those present.

NORTHWEST

Mr. F. H. Dill, Assistant to the Mechanical Engineer, American Bridge Company, spoke on the subject, "Designing for Structural Welding," at the April 23rd meeting of the Northwest Section, held at Minnesota Union, University of Minnesota.

OKLAHOMA CITY

The Oklahoma City Section was honored by a short visit from the Technical Secretary and Editor of THE WELDING JOURNAL, Mr. Wm. Spraragen of New York, on April 16th. Due to the fact that Mr. Spraragen was unable to be in Oklahoma City for a night meeting, the officers, members of the Executive Committee and Chairmen met with him for a luncheon.

A number of topics were discussed. These related to increasing the activities and interest in the Section through joint meetings, inspections and the like, increased returns on membership dues, the research work of the Society, how to improve the JOURNAL from a practical viewpoint, assistance in securing speakers, cooperation in membership activities and the like. The Section expressed desire that Mr. Spraragen return in the fall to deliver a technical talk.

During the month of May the Oklahoma City Section of the AMERICAN WELDING SOCIETY has been very active in connection with their educational program, as well as the regular monthly meeting. A series of three lectures was started on May 3rd by Mr. Orville T. Barnett, Metallurgist for Black, Sivalls & Bryson, Inc., for the conclusion of the educational program. The subjects of these three lectures are as follows:

May 3rd—"Steel," covering the manufacture of steel.

May 15th—"Crystals—What They Are and How They Are Formed."

May 22nd—"Temperatures—Influence of Temperature on Welding."

In the first lecture which has already been completed, Mr. Barnett covered the manufacture of steel, describing the processes in the blast furnace, open hearth and Bessemer converter. This first lecture was attended by a group of 25 members who followed the subjects with interest and brought up a number of questions regarding the construction of the furnaces and processes following the lecture.

The regular monthly meeting was held on May 10th at the Biltmore Hotel. The technical address was preceded by a film furnished by the Department of the Interior entitled, "Through Oil Lands of Europe and Africa." This film described the domestic life of central Europe and methods used in that country for producing and marketing of oil.

Mr. John Plaskon, Welding Engineer for the Metal and Thermit Corporation of Chicago, Illinois, gave a very interesting talk on the manufacture of welding rods and their application. In his talk Mr. Plaskon described the methods and uses of the different coatings (cellulose and mineral) for welding rods, showing pictures and describing the welding of large machine castings such as presses, reduction gears and receivers. His talk was illustrated with slides showing these various pieces of equipment.

There were 27 present for the meeting.

PHILADELPHIA

A most successful meeting was held on April 15th. Mr. David Arnott, Vice-President and Chief Surveyor, American Bureau of Shipping, addressed the meeting on the subject, "Use of Welding in Ship Construction."

The following officers were elected for the fiscal year: *Chairman*, H. W. Lawson; *Vice-Chairman*, Arthur J. Raymo; *Treasurer*, R. D. Thomas; *Secretary*, H. E. Hopkins.

An annual inspection trip was held on May 16th to the plant of the Lukens Steel Company, Coatesville, Pa. The Lukens Steel Company arranged a luncheon for the first one hundred who made the inspection trip. The inspection trip started at 2:00 o'clock and was enjoyed by all those present.

PITTSBURGH

Continued growing interest in the Tri-State Conferences held annually by the Pittsburgh Section was demonstrated Friday, April 26th, when the Third Annual Conference was held jointly with the Engineers' Society of Western Pennsylvania in the William Penn Hotel.

One hundred fifty-five members and guests took advantage of the opportunity to visit the Dravo Corporation plant in Neville Island and were treated to one of the most successful visitations ever enjoyed. About one hundred twenty were transported to and from the plant via motor buses, the others using their own cars, etc.

At the plant, under the personal supervision of Mr. C. P. Streithof and his aides, groups of ten were conducted through the structural and plate shops, bending and forming departments, through the assembling buildings and finally to the modern Barge Assembly yard, where barges in process of assembly were inspected and finally to the outside yard where the movement of a completed barge—30 ft. 0 in. x 400 ft. 0 in. x 11 ft. 0 in. deep was made and a similar type barge was launched.

The entire visitation was carefully scheduled and followed so that promptly on time, at 1:15 P.M., a luncheon was furnished all members and guests in the beautiful Dravo Cafeteria in time to allow return to the Hotel at 2:30 P.M. for the afternoon session.

Over three hundred attended the afternoon session and heard lectures by the following:

C. H. Jennings on "Distortion Problems;" Dr. A. B. Kinzel on "Low Alloy Steels for Welding;" H. W. Lawson on "Modern Steel Structures."

Slides were used to illustrate the lectures and open discussions followed each in turn.

A Door Prize—a copy of the 1938 A. W. S. Handbook—was won by J. E. Jackson, President of the Pittsburgh-Des Moines Steel Company.

Following the afternoon session a "get-together" dinner was held in the hotel grill room and was attended by eighty-four, including speakers.

The evening session was attended by over one hundred fifty members and guests.

Mr. Wm. Spraragen, Technical Secretary and Editor, gave a most interesting talk on the "AMERICAN WELDING SOCIETY, Its Aims, Purposes and Accomplishments" which was very well received.

The speaker of the evening, Mr. G. T. Horton, President of the Society and President of the Chicago Bridge & Iron Company, proved a most entertaining speaker and kept up an interesting discourse on the fabrication of welded structures, both by his own company and many others.

In the absence of Chairman Geo. F. Wolfe, who was called suddenly on business to the West Coast, Vice-Chairman A. E. Marble conducted all sessions in a most satisfactory manner.

The meeting closed with a vote of thanks to the Dravo Corporation for their splendid cooperation in extending the invitation for the plant visitation, the speakers, both in the afternoon and evening sessions and to the Engineers' Society of Western Pennsylvania for their hearty cooperation in putting over what is considered the best conference to date.

PUGET SOUND

A field inspection trip to the Seattle-Tacoma Shipbuilding Co., Tacoma, Wash., was made by the Puget Sound Section on May 10th. The speakers during the tour were Walter Green, Vice-President and General Manager, Seattle-Tacoma Shipbuilding Co., and Sidney Smith, American Bureau of Shipping.

ROCHESTER

Colonel G. F. Jenks, Ordnance Dept., U. S. Army, was the speaker at the May 2nd meeting of the Rochester Section held at Todd Union, University of Rochester. Col. Jenks's subject, "Some Unknown Factors in Welding," covered some of the welding problems he has met in working with the Ordnance Dept. and with the Welding Research Committee.

ST. LOUIS

Mr. F. G. Flocke of the International Nickel Co., New York, presented an interesting lecture on "Fabrication of Monel, Nickel, and Inconel in Solid and Clad Plate Constructions" at the May 10th meeting held in the Engineers' Club Auditorium.

WASHINGTON, D. C.

The Washington Section held its annual dinner meeting at the Harrington Hotel on April 23rd. About one hundred fifty people were present, among whom were the following guests of honor: Dr. Phillips Thomas, Dr. C. A. Adams, H. N. Ewertz, J. W. Meadowcroft, J. H. Deppeler, C. A. McCune, A. J. Moses, L. C. Bibber, R. W. Clark.

Miss M. M. Kelly, Secretary of the Society, was also present. A number of representatives of the Baltimore Section added to the list of out-of-town visitors.

The guests of honor, among whom were several past-presidents, were introduced and in their comments briefly recited events in the early history of the Society. Mr. C. A. Loomis, Chairman, then reviewed the activities of the past year, including the educational program made possible chiefly by the energy of Mr. George Knox, Secretary. All officers were credited for their cooperation and for the considerable increase in membership of the Section.

A humorous touch was added when time came for the presentation of the Chairman's pin to Mr. Loomis when, in addition to conferring the usual token, Past-Chairman A. G. Bissell presented an especially large button and ribbon about two feet long.

The following officers and executive committee were elected for the ensuing year and were introduced at the dinner:

Chairman, Commander C. A. Trexel (CEC) U. S. N.; Vice-Chairman, C. E. Meissner; Secretary, Edgar Brooker; Treasurer, R. F. Wood.

Executive Committee for two years: C. A. Loomis, W. F. Dietz, R. B. Swope, J. W. Wilson, A. G. Bissell, J. L. Bates.

Executive Committee for one year: F. B. Olcott.

Commander Trexel named Mr. A. G. Bissell chairman of the Program Committee and Mr. G. E. Knox chairman of the Membership Committee.

The climax of the evening took place after adjournment of the dinner meeting to the U. S. Department of Commerce auditorium, where Dr. Phillips Thomas, guest speaker from the Westinghouse Electric Company, departed from the usual field of the Society's interest and gave a very interesting illustrated lecture on the subject "New Horizons of Science," a subject directly pertinent to the progressive aims of the Society. Dr. Thomas demonstrated a "Precipitron" for air cleaning, the use of light for transmission of sound and control of mechanical apparatus, the sterilamp and its bactericidal properties, the new Westinghouse alloy, K-42-B, which possesses great strength at elevated temperatures, black light, in addition to a number of other physical phenomena which, though they may have no direct practical application now, may become of great value for future applications of scientific discoveries. The attendance at this lecture was about four hundred fifty.

WESTERN NEW YORK

The Western New York Section had a very enthusiastic meeting on April 22nd. The speaker was Mr. George Le Tourneau, President of R. G. Le Tourneau, Inc., Peoria, Ill. His subject was "Welding on the Drafting Board." The meeting was the biggest the Section had this year and was one of the most interesting.

WICHITA

The April meeting was held on the 15th at Wolf's Cafeteria. Mr. Wm. Spraragen, Technical Secretary of the AMERICAN WELDING SOCIETY, presented an interesting talk on the subject of "Resistance of Welded Joints to Impact and Fatigue Stresses."

An annual election of new officers for 1940 was held after the meeting and the following were elected to carry on the activities of the Wichita Section:

Chairman, Harry Christopher; *Vice-Chairman*, G. E. Drake; *Secretary*, K. O. Houser; *Treasurer*, H. C. Bates.

YORK–CENTRAL PA.

On April 24th Mr. J. H. Zimmerman, Development Engineer with The Linde Air Products Company, spoke on "Flame Cutting and Flame Machining." This involved a discussion of the various industrial flame-cutting applications, such as plate cutting, shape cutting, plate edge preparation and similar flame machining operations. Mr. Zimmerman had some very interesting slides which well illustrated his talk.

EMPLOYMENT SERVICE BULLETIN

SERVICES AVAILABLE

A-355. Welder. Complete course in Acetylene and Electric Welding. Knowledge A. W. S. Welding Code. Age 25. Ambitious, alert, willing worker. Go anywhere.

A-356. Welder, Electric Arc and Gas Cutting. Have 180 hours' actual practice. Ambitious, hard and willing worker. Can produce reference.

A-357. Student Welder, age 27, desires position as Assistant Welder to eventually work into research or sales division. Has had courses in electrical and mechanical engineering and over six years communication and switchboard in the 212th Coast Artillery.

A-358. Welder with five years' experience. Worked for American Locomotive as first-class welder and later as gang foreman of 14 welders; inspected welding jobs and taught men how to improve their welding. Worked in shipyard for some time. Would like job in South America, Central America, Panama or any place outside U. S.

A-359. Welder. Took six months' course at National Institute School of Welding. Can read blueprints. 28 years of age. Willing to work in New York City or anywhere in New Jersey.

A-360. Construction Engineer desires position. Have just completed some work for the Central Nebraska Public Power District and wish to make connection with some company as construction engineer. Thoroughly familiar with welded structural work, riveting and concrete. Can handle any type of construction work from start to finish. Available immediately. Location anywhere.

A-361. Mechanical and Electrical Engineer. 2 college degrees. Sound experience in welded design (code work), welding research and development, physical and X-ray tests, improving devices and methods. Seeks position as designer, production engineer or in research and instruction.

POSITION VACANT

V-94. Wanted, Welding Engineer with production experience. Company manufactures gasoline pumps, oil burners, small tanks and similar products, and want a man to help in production engineering and welding problems as they apply to these products. Do various types of welding—gas, electric, spot, resistance, etc. Would like man between 35 and 45. Firm located in Massachusetts.

List of New Members

April 1st to April 30, 1940

BOSTON

Goehringer, E. E. (C), 319 Lincoln St., Worcester, Mass.

CANADA

Clark, G. L. (D), Elm Creek, Manitoba, Canada.
Laughton, James A. (B), Hamilton Bridge Co. Ltd., Hamilton, Ont., Canada.
Tomlin, Alfred J. (D), 74 Park Avenue, Brantford, Ont., Canada.

CHICAGO

Doerner, Otto (C), 6001 W. Dickens Ave., Chicago, Ill.
Robbins, Mayson C. (C), Handy & Harmon, 20 No. Wacker Dr., Chicago, Ill.
Stephan, Frank A. (D), 1664 So. Christiana Ave., Chicago, Ill.
Vendl, Thomas (D), 2556 So. Western Ave., Chicago, Ill.

CINCINNATI

Bergmann, Frank (C), Box 44, Cleves, Ohio.
Campbell, Walter M. (C), The Breese Bros. Co., 2347 Reading Rd., Cincinnati, Ohio.
Haase, H. P. (D), 1671 First Ave., Price Hill, Cincinnati, Ohio.
Kaser, William (D), 16 Glenwood Ave., Cincinnati, Ohio.
Miller, Oliver W. (C), 114 W. Laird St., Cleves, Ohio.
Noppert, John W. (D), Addyston, Ohio.
Vaught, John E. (D), 329 Foote Ave., Bellevue, Ky.

CLEVELAND

Black, W. A. (B), Steel & Tubes Div. of Republic Steel Co., 224 E. 131st St., Cleveland, Ohio.
Hudnack, M. (D), 3365 W. 59th Place, Cleveland, Ohio.
Lincoln, James F., Jr. (D), Lincoln Elec. Co., Coit & Kirby, Cleveland, Ohio.
Wagner, Joseph F. (C), 4322 Woodbridge Ave., Cleveland, Ohio.

DETROIT

Bonnett, B. (D), 937 Moy Ave., Windsor, Ont., Canada.
Boychuk, Mike (D), 1092 Hickory Rd., Windsor, Ont., Canada.
Edwards, George C. (D), 1090 Moy Ave., Windsor, Ont., Canada.
Fournier, George (D), 1447 Ford Blvd., Sub. P. O. No. 11, Sandwich East, Ont., Canada.
Merriman, Clem G. (C), 17343 Birwood, Detroit, Mich.
Scibor, Frank (D), 1437 Langlois Ave., Windsor, Ont., Canada.
Walker, John A. (D), 1346 Bernard Rd., Windsor, Ont., Canada.

GEORGIA

Reid, W. L. (D), Austell, Ga.

HAWAII

Evans, E. W. (C), Hawaiian Gas Prods. Co., P. O. Box 2454, Honolulu, T. H.

INDIANA

Dimmett, Cecil (D), 401 Grand Ave., Indianapolis, Ind.
Hauntz, Leo A. (D), 933 No. Kealing, Indianapolis, Ind.
Pearcy, Percy (D), 1130 No. Dearborn St., Indianapolis, Ind.
Pipper, Rolland G. (D), 2524 Lincoln St., Anderson, Ind.
Rawlings, Gale F. (D), 99 No. Ritter, Indianapolis, Ind.
Volkel, Ellis (D), Perrysville, Ind.

LAKE SHORE

Shimek, Frank W. (D), 2501—10th St., Two Rivers, Wis.
Smith, Edwin R. (C), American Bureau of Shipping, 104 N. 8th St., Manitowoc, Wis.

LOS ANGELES

Greyerbiehl, Harold W. (C), 5555 Gravois Ave., Los Angeles, Calif.
Mackniesh, Frank (B), 1635 El Rito Ave., Los Angeles, Calif.
Messersmith, John (D), 1801 W. San Fernando Road, Burbank, Calif.
Ricker, Wm. S. (D), 1320 Park Ave., Inglewood, Calif.
Smith, Willard F. (C), Superior Tank & Const. Co., 6155 S. Eastern Ave., Los Angeles, Calif.

MILWAUKEE

Rogers, Charles (C), Crucible Steel Casting Co., 2850 So. 20th St., Milwaukee, Wis.

NEW YORK

Bruce, Leo I. (C), Lehigh Structural Steel Co., 17 Battery Place, New York, N. Y.
Goodman, Charles H. (C), Goodweld Equip. Co., 639 W. 125th St., New York, N. Y.
Langfur, Jacob (B), 36 W. 44th St., New York, N. Y.
Morales, Robert J. (D), Universal Welding Service Co., 236 W. 60th St., New York, N. Y.
Tuttle, Daniel A. (D), 145 W. 78th St., New York, N. Y.

NORTHERN NEW JERSEY

Alessandro, N. D. (C), Welding & Cutting Equip. Co., 51–53 So. 8th St., Newark, N. J.
Ballinger, Vernon (D), 1041 Avenue C., Bayonne, N. J.
Bucknam, James H. (B), The Linde Air Products Co., 686 Frelinghuysen Ave., Newark, N. J.
Eisensee, Arthur T. (C), Chicago Bridge & Iron Co., 119 Long Ave., Hillside, N. J.
Fomen, Leonard (D), 520 Mac Donald St., Garfield, N. J.
Inskeep, H. V. (B), The Linde Air Products Co., 686 Frelinghuysen Ave., Newark, N. J.
Jacobsson, Wilgot J. (B), The Linde Air Products Co., 686 Frelinghuysen Ave., Newark, N. J.
Jones, Homer W. (B), The Linde Air Products Co., 686 Frelinghuysen Ave., Newark, N. J.
Katchen, Alex (C), Irvington Steel & Iron Works, 487–493 Lyons Ave., Irvington, N. J.
Kee, John H. (D), 31 Prospect Place, Bound Brook, N. J.
Kielb, Joseph V. (C), 1733 Springfield Ave., Maplewood, N. J.
Komleski, Edward, Jr. (D), 130 Longfellow St., Carteret, N. J.
Kurzina, Edward (D), Fairfield Ave., West Caldwell, N. J.
Lelless, Cecil (D), 172 Cambridge St., Garfield, N. J.
Manning, John J. (B), Industrial School of Welding, 185 Ogden St., Newark, N. J.
Milligan, Paul (D), 120 Madison Ave., Elizabeth, N. J.
Rea, John (D), 148 Re Hart Pl., Elizabeth, N. J.
Tarasavage, Joseph (D), 43 President St., E. Newark, N. J.
Todd, Alan (D), 70 Rutgers St., Maplewood, N. J.
Vertk, Joseph (D), 191 N. 15th St., E. Orange, N. J.
Weiss, Joseph H. (C), Trex Engrg. & Supply Co., 611 McCarter Highway, Newark, N. J.

WESTERN NEW YORK

Heinz, Edward F. (B), Buffalo Fdy. & Mach. Co., 1543 Fillmore Ave., Buffalo, N. Y.

NORTHWEST

Dean, William B. (D), 528 Russell Ave., No., Minneapolis, Minn.
Hall, Carl R. (C), 2922 W. 44th St., Minneapolis, Minn.
Johnson, Caleb C. (D), 2410 Johnson St., N. E., Minneapolis, Minn.
Moebins, Joseph L. (D), 726—9th Ave., S. E., Minneapolis, Minn.
Nelson, George H. (D), 3641—42nd Ave., So., Minneapolis, Minn.
Porter, Arthur A. (D), 4030—3rd St., N.E., Minneapolis, Minn.
Ranney, M. E. (D), 2745 Ewing Ave. No., Minneapolis, Minn.
Thompson, Clifford (D), 1204 Lincoln St. N. E., Minneapolis, Minn.
Volk, D. E. (D), 2355 Thomas Ave. No., Minneapolis, Minn.
Wineland, Carl (D), 7329 Colfax Ave. So., Minneapolis, Minn.
Woods, Carl E. (D), 22 W. Grant St., Minneapolis, Minn.
Zappa, Anthony M. (D), 2305 E. 24th St., Minneapolis, Minn.

PHILADELPHIA

Carey, Clarence E. (D), Bristol Road, Ivyland, Pa.
Colby, Haldwell S. (B), 2575 Hillcrest Road, Drexel Park, Pa.

Crudden, Joseph A. (B), 5330 Angora Terrace, Apt. A, Philadelphia, Pa.
Jansen, John (D), 7211 Charles St., Philadelphia, Pa.

PITTSBURGH

Doering, Roger W. (B), 11413 Clematis Blvd., Wilkinsburg, Pa.
Fullman, J. M. G. (B), 904 Beaver St., Sewickley, Pa.
Kerr, William E. (B), Pennsylvania Transformer Co., 1701 Island Ave N. S., Pittsburgh, Pa.

PUGET SOUND

Dickinson, R. E. (D), 908 W. 70th St., Seattle, Washington.
Niccolls, Robert S. (B), 2211—10th Ave. No., Apt. C., Seattle, Washington.
Pim, E. H. (B), General Elec. Co., 1525 Exchange Bldg., Seattle, Wash.
Styer, C. M. (C), Pacific Car & Fdy. Co., 220 W. Hudson St., Seattle, Wash.
Winship, Ralph (C), 5537—26th N. E., Seattle, Wash.

ROCHESTER

Ackerman, Clarence J. (D), Rochester Gas & Elec. Co., Gen. Maintenance Dept., Rochester, N. Y.
Mitchell, E. W. (C), Rochester Gas & Elec. Co., General Maintenance Dept., Rochester, N. Y.
Potter, Samuel (D), Rochester Gas & Elec. Co., Gen. Maintenance Dept., Rochester, N. Y.

ST. LOUIS

Eagle, S. S. (B), % American Car & Fdy. Co., Madison, Ill.
Lawler, J. W. (B), % American Car & Fdy. Co., St. Charles, Mo.
Leonard, B. H. (B), Midwest Piping & Supply Co., 1450 S. 2nd St., St. Louis, Mo.

SAN FRANCISCO

Christy, Robert E. (B), United Engrg. Co., 298 Stewart St., San Francisco, Calif.
Odell, Wray N. (D), 710 E. Grove St. N., Sacramento, Calif.
Sullivan, C. R. (A), Moore Machinery Co., 1665 Van Ness Ave., San Francisco, Calif.

SOUTH TEXAS

Remington, C. L. (D), P. O. Box 1954, Port Neches, Texas.

TULSA

Dunnam, F. S. (C), 722 N. Evanston, Tulsa, Okla.
Miller, J. D. (D), 113 S. Denver, Tulsa, Okla.
Moheng, Howard (C), 1115 W. 16th Place, Tulsa, Okla.
Thompson, Jack (D), 113 S. Denver, Tulsa, Okla.

WASHINGTON, D. C.

Sampson, D. S. (C), A. M. Byers Co., 1040 Shoreham Bldg., Washington, D. C.

WICHITA

Butters, Carl (D), 720 E. Harvey, Wellington, Kansas.
Weber, Leroy E. (C), Skelly Oil Co., El Dorado, Kansas.

YORK

Herman, Harry S. (D), 13 E. High St., Windsor, Pa.
Hindman, W. P. (B), % American Car & Fdy. Co., Milton, Pa.

NOT IN SECTIONS

Brekken, Obert J. (D), Carpio, No. Dakota.
Prime, Arthur E. (D), Brooks, Maine.

FLAME CLEANING

"Flame Cleaning and Dehydrating Iron and Steel," an 8-page illustrated booklet, has just been issued by Air Reduction, 60 East 42nd Street, New York.

The first part of the booklet is devoted to a reprint of a recent magazine article, "Maintenance Painting on the Golden Gate Bridge," written by R. G. Cone, Engineer, Golden Gate Bridge and Highway District. The article discusses the various problems encountered in the task of keeping the huge bridge in proper condition, and what means were utilized to overcome these problems. Mr. Cone explains how Airco equipment was employed in flame cleaning and dehydrating operations.

Rounding out the booklet is the text of a paper delivered by F. H. Frankland, Chief Engineer, American Institute of Steel Construction, at the Annual Meeting of the American Toll Bridge Association. In his message entitled, "The Cleaning and Painting of Bridge Steel," Mr. Frankland discusses the economy of efficient maintenance of steel structures, and the important part played by flame cleaning in this program.

Copies of this booklet, ADG-1073, may be obtained by writing to Air Reduction Sales Co., 60 East 42nd Street, New York, N. Y.

OBITUARY

Walter S. Rugg

Walter S. Rugg, aged 74, retired Vice-President of the Westinghouse Electric and Manufacturing Company, and widely known throughout the electrical industry, as an engineering and sales executive, died April 25th, in New York after a heart attack.

Born in Broadhead, Wisconsin, he attended Laurence College in that state, and later Cornell University, where he graduated with a Master of Science degree in 1892. That same year he began his electrical career as a student engineer at Westinghouse. Three years later he went to the Chicago office as district engineer, later transferring to the sales force. From 1901 to 1917 he was in the New York offices, the last eight years as manager. Then he returned to the East Pittsburgh Works as manager of the Railway Department, and shortly afterward, of the Marine Department. In 1922 he became general sales manager of the Company, and in 1925 was elected Vice-President. In that office he was at one time in charge of both engineering and sales activities of the Company.

Mr. Rugg was an active member of the AMERICAN WELDING SOCIETY.

UNUSUAL FABRICATION IN MONEL

Specializing in the construction of chemical processing equipment to specification has brought an interesting variety of work to the plant of Liberty Coppersmithing Company in Philadelphia, Pa., and because different processes call for the use of various materials this concern maintains a personnel experienced in forming and in welding all of the commercial metals and alloys. Many a finished unit may look like a simple container on the outside and yet involve some difficult design details inside. Typical of this condition are the two monel jobs illustrated. Figure 1 is a view inside a mixing tank, 4 feet in diameter by 5 feet deep, made of $^{3}/_{16}$-inch monel plate. Figure 2 is a sulphonator. Here a 6-foot diameter monel tank is entirely enclosed in a steel jacket, the whole being entirely arc welded.

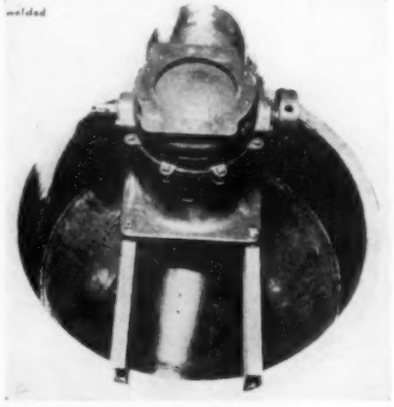
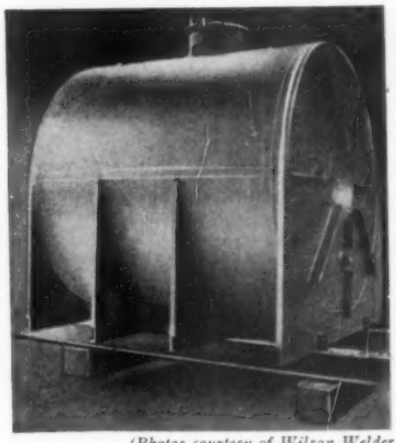


Fig. 1



(Photos courtesy of Wilson Welder and Metals Co., Inc.)

Fig. 2

ANNUAL MEETING
CLEVELAND
OCT. 20-25, 1940

KEEP WELDING COSTS DOWN WITH MUREX GENEX

The SPEEDY, EASY-TO-USE ALL-POSITION ELECTRODE FOR STRAIGHT POLARITY OR A. C. WELDING.

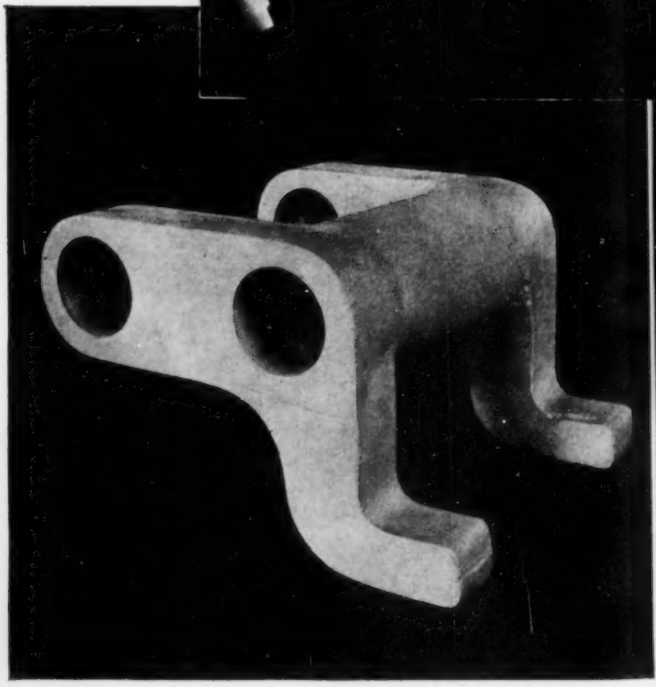
This is the welding electrode used for a wide variety of work by many important fabricators of welded products.

Designed for welding in any position . . . flat, vertical, or overhead . . . and to readily bridge gaps where assembly fit-up is imperfect, Murex Genex Electrodes have several outstanding features which make them highly economical in operation. They are used at higher currents, which steps up welding speed. They burn with less spatter; less smoke, and so provide better visibility of the arc and the molten pool of weld metal. The slag is easy to remove and does not cling to the edges of the weld, even on heavy fillets.

Genex can save you money in structural work, in lap welding where single-pass fillets of ½ to ⅜ in. are required, in fabricating gear and fan housings, in the building of air ducts and other parts of light gauge metal, and in many other applications. Send for complete information, or ask to have a representative call and show you what these electrodes can do.

In marine work, Genex speeds work where lap welds are required on bulkheads and hull plating.

Easy to use. Genex Electrodes are often employed in making small units to replace castings, such as this one built by The Dorr Company, Denver.



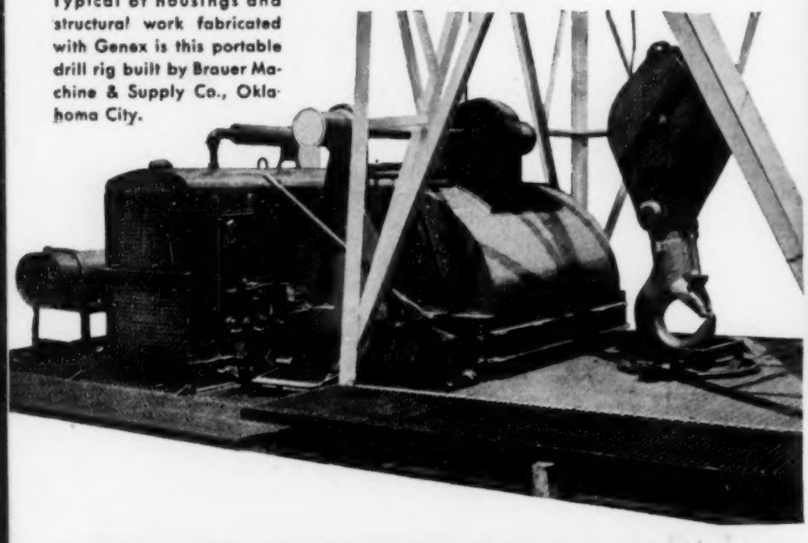
METAL & THERMIT CORPORATION

"Murex Electrodes—Thermit Welding—Thermit Metals & Alloys."

120 Broadway, New York, N. Y.

Albany • Chicago • Pittsburgh • So. San Francisco • Toronto

Typical of housings and structural work fabricated with Genex is this portable drill rig built by Brauer Machine & Supply Co., Oklahoma City.



Investigate Thermit Welding, too—in use since 1902 for heavy repair work, crank shafts, etc.

MUREX

HEAVY COATED *Electrodes*

A COMPLETE LINE FOR EVERY WELDING APPLICATION